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The Journal of
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PAINFUL SHOULDER

Observations on the Role of the Tendon of the Long Head of the Biceps Brachii in Its Causation *

BY HAROLD H. HITCHCOCK, M.D., AND CHARLES O. BECHTOL, M.D., OAKLAND, CALIFORNIA

From the Department of Orthopaedic Surgery, Samuel Merritt Hospital, Oakland

Lesions affecting the tendon of the long head of the biceps brachii are among the more frequent causes of pain and disability in the region of the shoulder joint. Observation and inquiry disclose that, in the majority of cases, common predetermining factors are responsible for the several pathological conditions encountered, an appreciation of which serves materially in problems of differential diagnosis and in the selection of rational procedures for the correction of dysfunction. Of these predetermining factors, the most significant are the presence of the "supratubercular ridge" of Meyer (described in 1928) and a preternaturally shallow bicipital or intertubercular sulcus which, with excessive function or as the outcome of trauma, results in a variety of lesions; these include acute or chronic peritendinitis, varying degrees of attrition and damage to the tendon, and its partial or complete dislocation. In addition, phylogenetic and functional considerations are important for an understanding of the high degree of vulnerability of this tendon,—a liability which man has had to assume in his compromise with Nature by the adoption of the erect posture.

Prior to a discussion of matters of etiology, differential diagnosis, and treatment, it would perhaps be advisable to consider and discuss the brief reports of four cases which exemplify some of the conditions mentioned.

Case 1. W. F., a male, aged sixty, had fallen six months before and struck the flexed elbow of the right arm. Three weeks later he had pain in the right shoulder, which radiated down the front of the arm. The pain continued and the patient lost the ability to move his shoulder.

Examination showed almost no motion in the shoulder joint. Attempted passive motion was accompanied by severe pain. Great tenderness was elicited by pressure over the bicipital groove. Roentgenograms revealed no pathological changes, and the bicipital groove appeared to be of normal depth and configuration.

At operation the biceps tendon was found to be markedly injected; all of its sheen was lost. There were adhesions to the transverse humeral ligament and the groove, as well as to the deep aspect of the tendon of the pectoralis major. When the shoulder was elevated, the portion of the tendon lying in the upper part of the groove was observed to become lax and to buckle, owing to its adherence to the transverse humeral ligament. After the tendon had been freed in the bicipital groove, it could not be pulled upward. The biceps tendon was, therefore, fixed in the groove and the portion above the transverse humeral ligament was resected. The shoulder was then manipulated, and intra-articular adhesions were felt and heard to give. After this a free range of motion was possible.

Ten days after operation the patient was encouraged to carry the extremity through a full range of motion. Eight weeks after operation complete and painless motion had been established, and the patient returned to work.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1947.

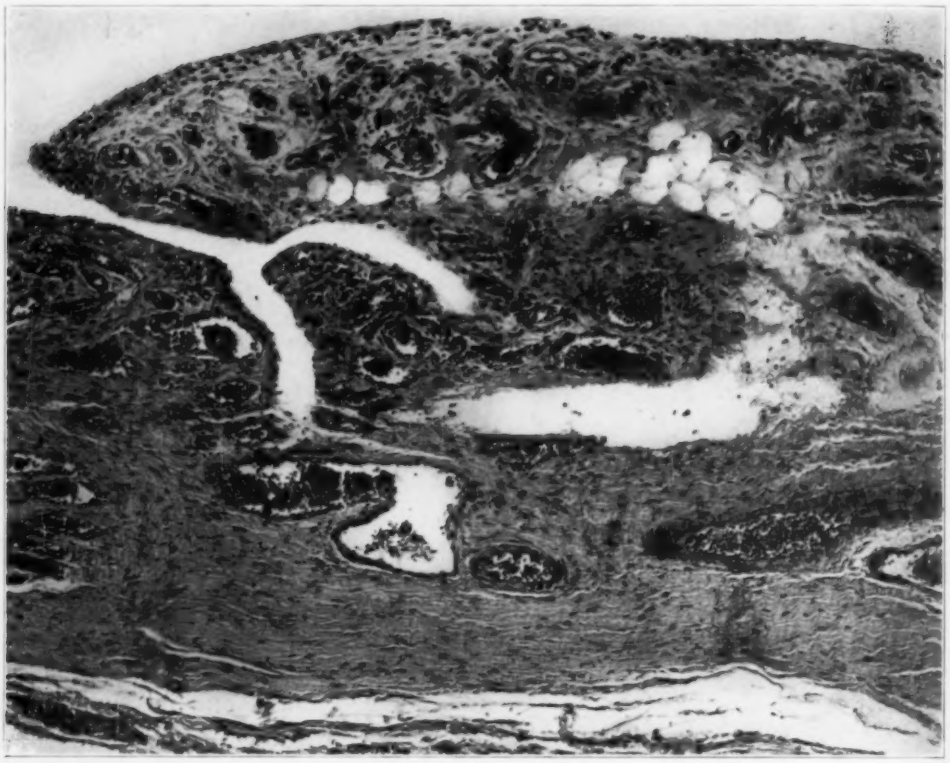

FIG. 1

Microscopic examination showed vascularization of the tendon and injection with lymphocytes and leukocytes (Fig. 1).

Operation disclosed adhesions, both within the joint and about the tendon of the long head of the biceps. Those adhesions involving the tendon interfered with the free play of the tendon within its groove, thus interrupting mechanically the function of the joint. Previous experience indicated that simple division of the adhesions about the tendon is inadequate, because of the rapidity of their reformation. Resection of the proximal portion of the tendon completely prohibits any possibility of interference of joint action by buckling of the tendon, and fixation of the distal portion in the line of its axial pull avoids the tissue distortion responsible for the recurrence of pain. Restoration of function and the loss of symptoms in this case were extremely rapid; the authors do not believe that such complete recovery could have taken place in the short space of eight weeks without operation.

Scapulohumeral periarthritis was described as early as 1872 by Duplay, who recorded the presence of adhesions within the subacromial bursa. The observations of this author were centered on the bursa to the neglect of a frequently accompanying peritendinitis, involving the long head of the biceps muscle. In consequence, he failed to appreciate the significance of pathological changes about this tendon in contributing to the disability. Since Duplay's report, greater consideration has been given to the effects of loss of the gliding space about the musculotendinous cuff in the production of the frozen shoulder than to the significant role of peritendinitis about the long head of the biceps muscle in producing a very large part of the functional difficulty.

In 1932, however, Pasteur recognized that peritendinitis affecting the long head was a cause of pain over the bicipital groove and was responsible for the limitation of motion at the shoulder joint. The reports of Meyer, Gilcreest, Schrager, Lippmann, Moseley, and Tarsy have made the nature of these lesions more widely known. Lippmann clearly demon-

strated the role of the tenosynovitis, by operation on thirty-two patients with frozen shoulder. In two of these cases he drew attention to the presence of adhesions within the subacromial bursa. On the other hand, Neviaser found capsular adhesions in ten such cases, but did not explore the tendon. Meyer has greatly extended our knowledge of the pathology of the subject by drawing attention to the more advanced stages of attrition which accompany excessive functional use. With the exception of Meyer, none of these writers has been able to advance a satisfactory etiological explanation for his findings.

CASE 2. In a male iron worker, twenty-five years old, acute burning pain developed in the right shoulder, following a straight downward pull. Following this initial strain, an uncomfortable snapping could be reproduced by rotation of the humerus in a slightly abducted position. Firm pressure over the bicipital groove would prevent the snapping. The extremes of motion were painful, and there was tenderness over the bicipital groove. Roentgenograms showed a shallow bicipital groove in each shoulder. No other bone abnormality could be seen.

Because of the discomfort and snapping in his shoulder, an operation was performed eight weeks after the injury. No abnormalities of the tendinous cuff or subacromial bursa were found. As a result of a shallow groove with a very lax roof, the tendon of the long head of the biceps could become dislocated inward onto the lesser tuberosity.

After the lateral half of the floor of the bicipital groove had been lifted and the tendon beneath it had been sutured, the tendon of the long head of the biceps was fixed into the bicipital groove. The portion above the transverse humeral ligament was resected. The patient made an uneventful recovery and returned to work eight weeks after his operation.

It is significant that this man was operated upon shortly after his initial injury. The shallow bicipital groove was present in each shoulder and was a contributing cause to the dislocation of the biceps tendon; it was not a result of changes produced by his injury.

Abbott and Saunders have recognized both recurrent dislocations without trauma and acute traumatic dislocation of the tendon. In discussing the anatomical factors favoring these dislocations, they draw attention to the varying relationship of the tendon to the groove in different positions of the extremity. Béra, in 1910, stated that malformation or localized osteitis reduced the height of the lesser tuberosity and was of prime importance in the occurrence of dislocation of the tendon. A similar view was propounded by Horwitz, who observed fraying of the tendon in association with such bony changes. On the other hand, Meyer noted many examples of spontaneous dislocation of the tendon in the absence of arthritis or anatomical abnormality about the tubercles, which led him to conclude that dislocation and severance of the tendon constituted a common outcome of the everyday wear and tear of use. Among other factors, he drew special attention to the significance of the supratubercular ridge in facilitating dislocation, but made no observation on the variations in depth of the groove.

CASE 3. V. M., a male, aged sixty-one, had wrenched his left arm two years before, while opening the turtleback of a car. He had severe pain in the front of his left upper arm at the time. This became less severe after the application of local heat, but sudden movements of the left shoulder caused severe pain in the shoulder. Finally the pain became continuous.

Examination showed pain with sudden movements of the shoulder, and tenderness over the bicipital groove. Anteroposterior roentgenograms revealed no bone abnormalities. Unfortunately, no films were taken to show the groove.

At operation the only pathological findings were about the biceps tendon. The bicipital groove was very flat. The tendon was dislocated inward from the bicipital groove, and was impaled on a sharp bony spur which projected from the lesser tuberosity. With movement of the shoulder, this spur frayed the tendon. The tendon was more than half cut through by it. There was a very loose fibrous sling about the tendon, which permitted it to lie in the abnormal position in which it was found.

The biceps tendon was fixed in the bicipital groove. The portion above the groove was resected, and the spur on the lesser tuberosity was removed with an osteotome.

The patient made an uneventful recovery and returned to work, with a full range of painless motion, eight weeks after the operation.

CASE 4. Nine months before, J. R. had fallen five feet and had struck on the point of the flexed left elbow. Following this he was unable to raise his left arm. Attempts to move the shoulder passively were painful. There was tenderness to pressure over the bicipital groove. Roentgenograms were negative.

At operation it was found that the long head of the biceps tendon had been dislocated inward over the lesser tuberosity from a normal-appearing groove. There was no fascial sling about the tendon, such as is seen with a recurrently dislocating tendon and shallow groove. There was an exostosis over the greater tuberosity, and adhesions between this and the deltoid muscle. The tendon was fixed in the groove, and the portion proximal to the transverse humeral ligament was resected. The exostosis and adhesions were resected. No further joint adhesions were felt to give when the arm was put through a full range of motion. Motion was begun ten days after operation. A full range of painless motion was possible in six weeks.

This represents a forceful dislocation of the long head of the biceps tendon, with trauma and adhesions to the greater tuberosity of the humerus.

ANATOMICAL OBSERVATIONS

In order to determine the incidence of the supratubercular ridge and variations in the depth of the intertubercular groove, as well as their significance in producing lesions involving the biceps tendon, 100 humeri were examined.

The Supratubercular Ridge of Meyer

The supratubercular ridge is a ridge of bone, projecting immediately proximal to the medial wall of the bicipital groove and continuous with it. The biceps tendon is limited by this structure from slipping inward and is forced upward against the transverse humeral ligament, thus favoring dislocation. Meyer reported that, in an unpublished study made by Cilley, this ridge was present in 17.5 per cent. of 200 humeri. In the present series it was found to be markedly developed in 8 per cent. of the humeri and moderately developed in 59 per cent. (Fig. 2). The relatively greater incidence in this series is accounted for by the fact that Meyer's report included only those meeting an exact anatomical configuration. We have, however, included all ridges which we judged were high enough to force the biceps tendon against the roof of the groove and thus cause trauma to the tendon. The fact that pressure against the fibrous roof and inflammatory changes have actually occurred from its presence is proved by the finding of a spur on the lesser tuberosity in 45 per cent. of the humeri of our series which showed a supratubercular ridge. On the other hand, in the absence of a supratubercular ridge, in only 3 per cent. of the humeri were spurs demonstrable on the lesser tuberosity (Fig. 2). Humeri showing any other hypertrophic changes are excluded from these percentages.

Variations in the Depth of the Groove

A marked variation in the depth of the bicipital groove exists, which is most conveniently expressed as the angle of the medial wall of the groove (Fig. 3). In 8 per cent. of the humeri, the medial walls of the groove made an angle of less than 45 degrees; this establishes a close correlation with Meyer's finding that 8 per cent. of biceps tendons were dislocated in a fascial sling from a shallow groove.

Comparative Anatomy of the Biceps Groove

Man is unique among the Primates in presenting marked variations in the conformation of the bicipital groove. The angle of the medial wall is identical in all specimens in the gorilla (22), chimpanzee (38), gibbon (28), and orangutan (18). The orangutan, which is an active climber, has the shallowest groove, with a medial-wall angle of 60 degrees. Supratubercular ridges are common in all of these species (Fig. 3).

Functional Anatomy

Contrary to what is often superficially thought, it is not the tendon which slides in the groove, but the humerus which moves on the fixed tendon during motions at the shoulder. From adduction to complete elevation of the arm, a given point in the groove moves along the tendon for a distance of at least one and one-half inches. In order to facilitate such motion, a synovial pouch extends from the shoulder joint to line the intertubercular groove

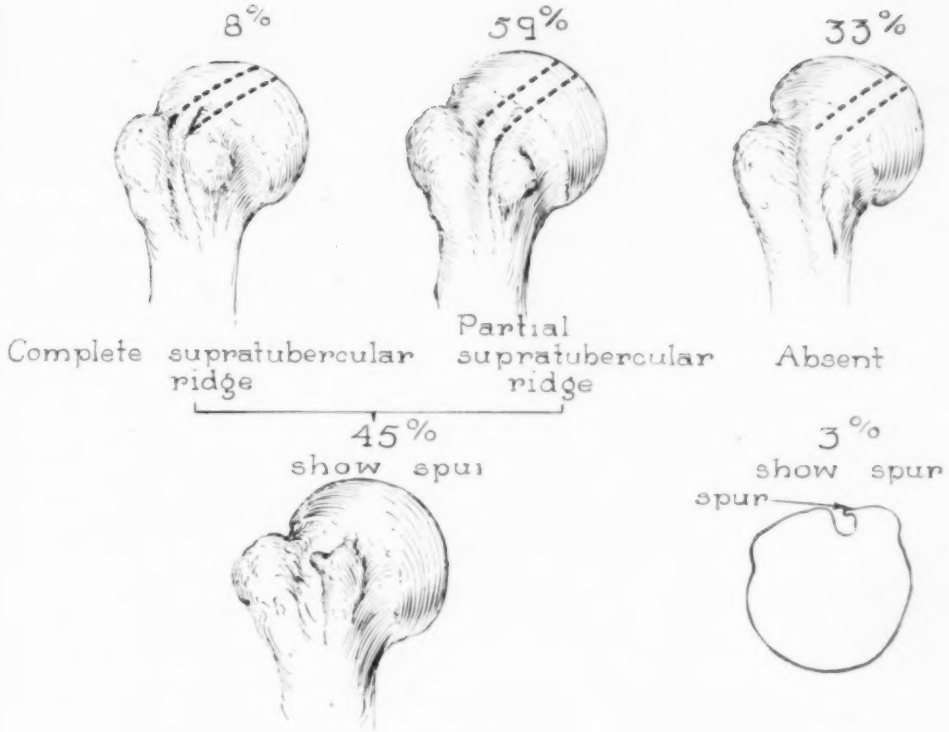
8%
59%
33%
Complete supratubercular ridge
Partial supratubercular ridge
Absent
45% show spur
3% show spur
spur

FIG. 2

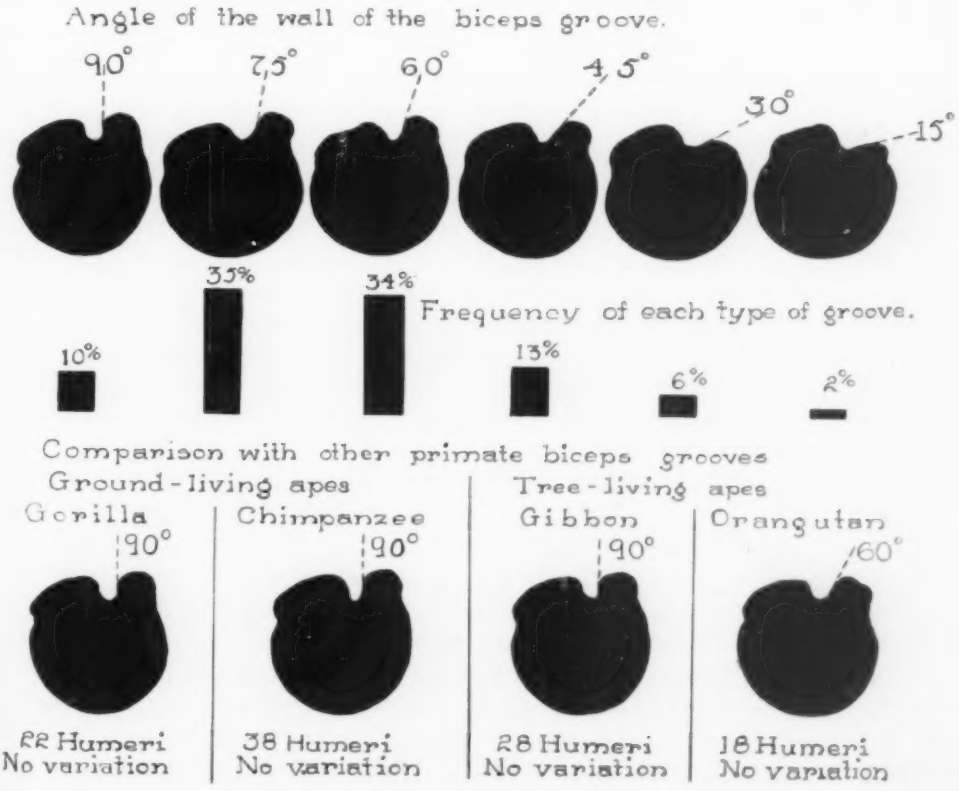
Angle of the wall of the biceps groove.
90°
75°
60°
45°
30°
15°
35%
34%
Frequency of each type of groove.
10%
13%
6%
2%
Comparison with other primate biceps grooves
Ground-living apes
Tree-living apes
Gorilla
Chimpanzee
Gibbon
Orangutan
90°
90°
90°
60°
22 Humeri
No variation
38 Humeri
No variation
28 Humeri
No variation
18 Humeri
No variation

FIG. 3

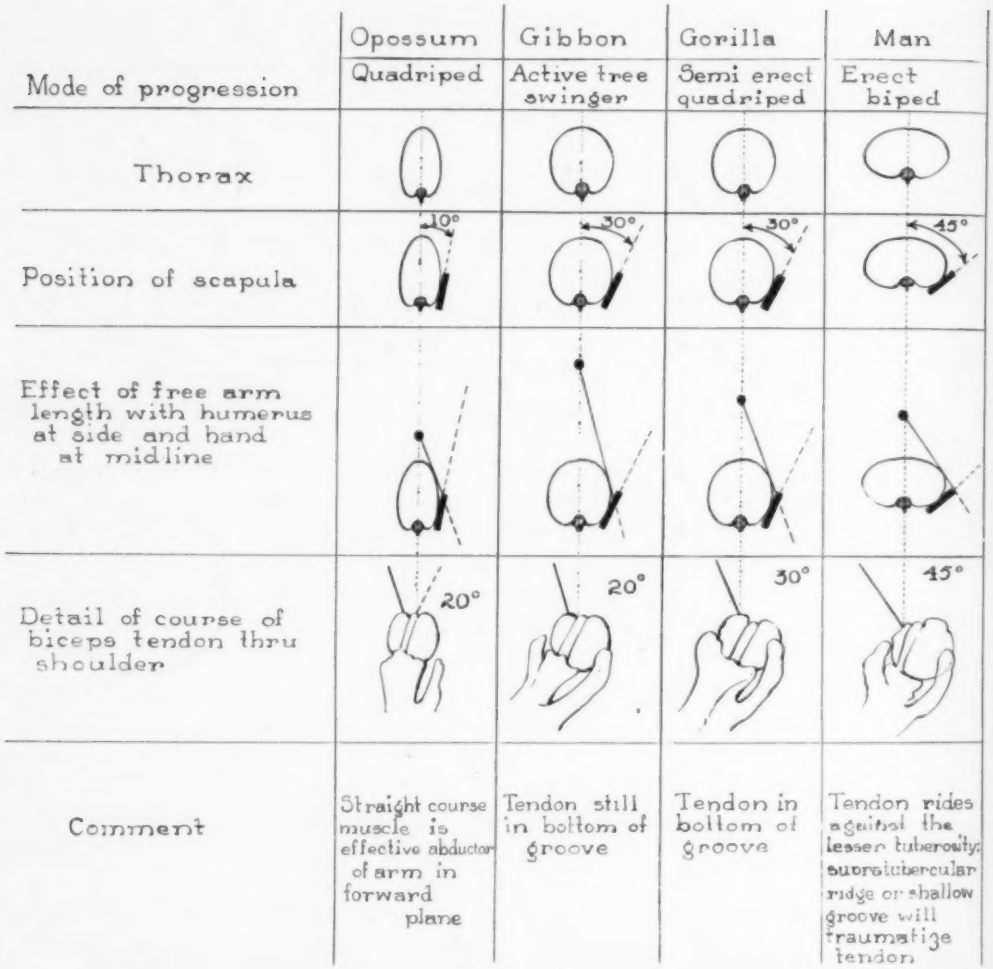

FIG. 4

for the greater part of its extent. Below this bursa, the tendon glides through its peritendineum.

Motion of the humerus on the tendon occurs in all movements of elevation at the shoulder, whether elevation be accomplished through the pathway of forward flexion or abduction. As these movements are nearly always associated with strong flexion and supination at the elbow, the long head of the biceps is rendered exceedingly taut. If, at the same time, the arm is medially rotated at the shoulder, the tendon plays on the medial wall of its groove and the lesser tubercle acts as a trochlea or pulley. On the other hand, when the arm is in full lateral rotation, the tendon occupies the floor of the groove, and its more proximal portion exercises pressure on the head of the humerus. Therefore, it is in lateral rotation only that the long head acts directly on the shoulder joint and enhances somewhat the power of abduction at this joint.

The Role of Oedema or Adhesions in Causing Pain

If, during motion, the tendon of the long head of the biceps is involved by adhesions, not only is the upward thrust of the humerus hindered, with consequent limitation of motion, but the pull is transferred to the adhesions and through them to the very sensitive surrounding tissues, such as the periosteum and fasciae. The pain is due in large measure to the effects of stretching the surrounding adhesions.

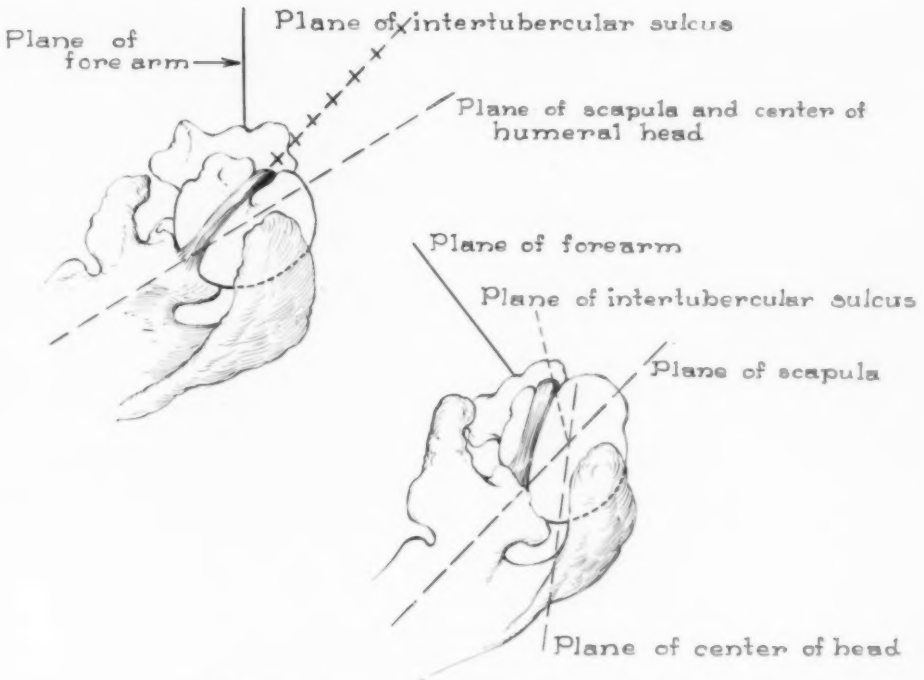
Plane of fore arm
Plane of intertubercular sulcus
Plane of scapula and center of humeral head
Plane of forearm
Plane of intertubercular sulcus
Plane of scapula
Plane of center of head
With the humerus in internal rotation (the position of common use) the biceps tendon is forced against the medial wall of the groove

FIG. 5

Anatomical Factors Responsible for Vulnerability of the Tendon

Neither the supratubercular ridge nor a shallow bicipital groove can cause injury to the biceps tendon, unless the tendon is forced against the lesser tubercle and medial wall of the groove. As has been pointed out, the tendon is commonly brought into relationship with this wall, as we habitually use the extremity in various degrees of medial rotation during elevation. A number of phylogenetic factors have been responsible in man for the gradual displacement of the tendon in the medial direction (Fig. 4). These factors are:

1. Anteroposterior flattening of the thorax, which leads to dorsal rotation of the scapula and lateral displacement of the glenohumeral joint.

2. A relatively short forearm which necessitates greater medial rotation of the humerus in order that the hand may reach the mid-line.

3. The anteroposterior flattening of the thorax and the short forearm are compensated for, but only incompletely, by torsion of the humerus and migration of the bicipital groove (Fig. 5).

Man has been unable to adapt himself fully to the requirements of an erect posture. Changes in thoracic shape necessitate the lateral position of the shoulder girdle, but functional demands of a prehensile extremity require its use in relationship to the ventral aspect of the body, thus establishing another example of conflict between function and structure. In the pronograde, the tendon of the long head of the biceps plays over the center of the hemispherical head of the humerus, to pass directly into its groove which lies in the same plane. The tendon is thus secure and remains a powerful force in elevation. In the orthograde, on the other hand, lateral migration of the shoulder girdle has, so to speak, left the tendon behind on the ventral aspect, in order that the muscle may continue to serve the function of the forearm. As a consequence, the groove no longer lies in the same plane as the center of the head, but makes an angle, according to Saunders and Inman, of

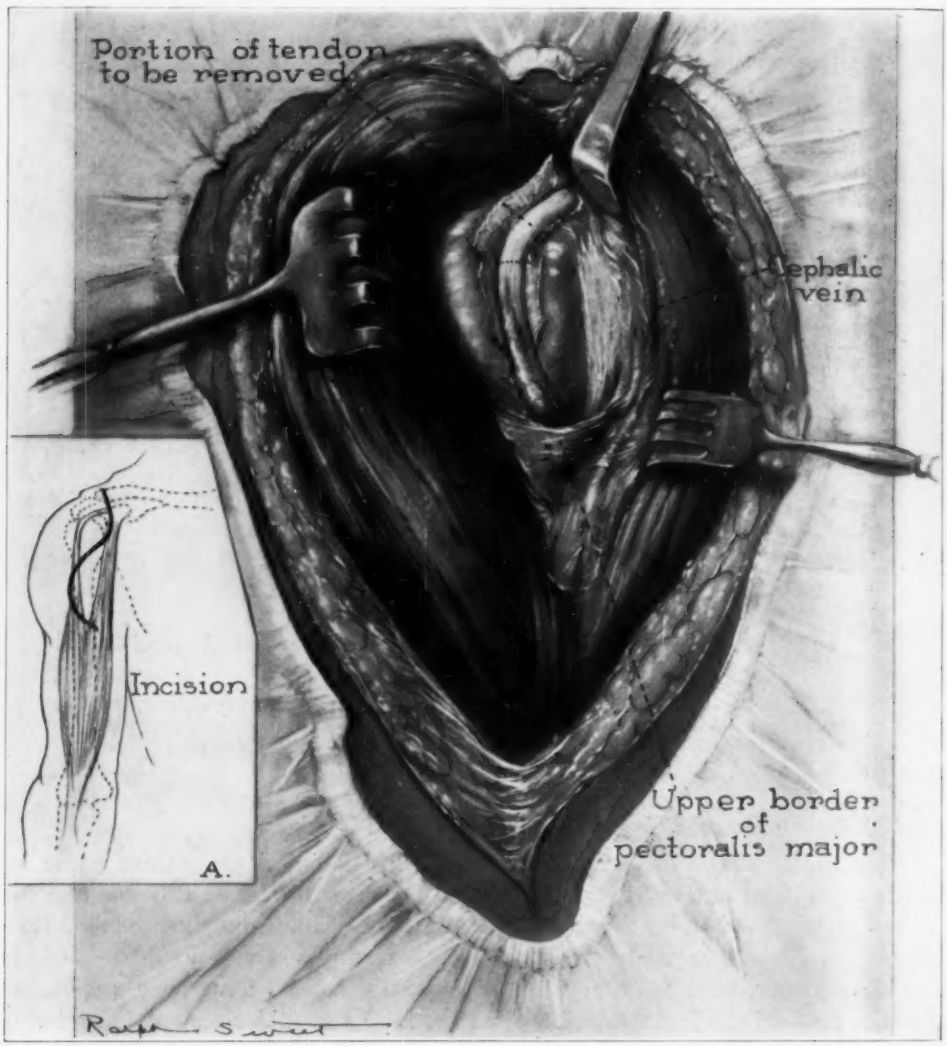

FIG. 6

30 degrees to it. The tendon now occupies a very insecure position which is compensated for, but very incompletely, by torsion of the humerus. Medial rotation of the humerus, to permit the hand to be brought to the position of function at the mid-line, further exaggerates the displacement of the tendon, which is forced to bear on the lesser tubercle and medial wall of its groove. Such a relationship renders the tendon in this region highly vulnerable, not only to the trauma of a single severe incident, but also to that of everyday function. A supratubercular ridge and a shallow groove enhance the likelihood of injury.

Relative Position of the Humerus in Various Mammals

In Figure 4 the relative shape of the thorax and the relative position of the scapula are shown for the opossum, the gibbon, the gorilla, and man. After a review of these, it might be argued that all the humeri have been placed in the human position, and that the various species make greatest use of their arms in other positions. This serves merely to emphasize the point that man habitually holds his humerus in abduction and internal rotation. Thus, in addition to having a poor anatomical arrangement, man's arm is held and used in a position which produces the greatest wear on the biceps tendon and makes dislocation more likely.

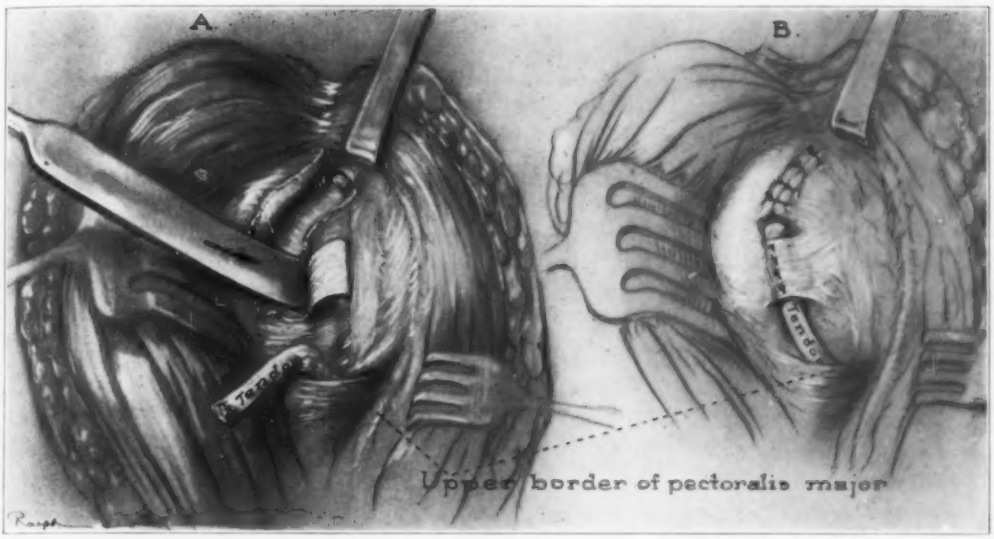

FIG. 7

DIAGNOSIS

In the presence of a lesion affecting the long head of the biceps muscle, the most constant physical finding is tenderness over the tendon. Tenderness may be found anywhere from the level of the tubercles and distally along the course of the tendon, or over the insertion of the pectoralis major, to the lateral lip of the intertubercular ridge.

Dislocation of the tendon, complete or incomplete, may be differentiated from a peritendinitis by the test of Abbott and Saunders. After full abduction of the shoulder, the arm, which is held in complete lateral rotation, is slowly brought down to the side in the plane of the scapula. A palpable or even audible, and sometimes painful, click is noted as the biceps tendon, now forced against the lesser tubercle, becomes dislocated from the groove.

Roentgenograms are, unfortunately, of little value, except for the purpose of excluding other types of lesions affecting the shoulder region. However, shallowness of the groove or the existence of a spur on the lesser tuberosity may be demonstrated in axial views. A supratubercular ridge can readily be seen in the usual anteroposterior films taken with the arm in external rotation; this provides presumptive evidence, in the presence of pain and tenderness over the groove, of possible damage to the tendon.

With a frozen, painful shoulder, failure of the condition to clear up quickly with manipulation and physical therapy, together with persistent tenderness over the intertubercular groove, very probably means inflammation and adhesions about the biceps tendon. It should not be forgotten that peritendinitis of the long head may be associated with other lesions about the shoulder, such as rupture of the tendon of the supraspinatus. In consequence, the peritendinitis may be overlooked, with resultant disappointment in the results of therapy.

TREATMENT

Manipulation under an anaesthetic, followed by balanced traction, has been used for the painful frozen shoulder. Where tenderness over the bicipital groove has been present, convalescence has usually been long and difficult. Fixation of the long head of the biceps tendon to the floor of the intertubercular groove, in the manner to be described, greatly expedites convalescence and promotes loss of pain and rapid functional recovery.

Where recurrent or traumatic dislocation of the biceps tendon is found, surgery is indicated.

Operative Procedure

An S-shaped skin incision over the deltoid-pectoral interval (Fig. 6) serves to lessen the tendency to hypertrophied scar, which is common when a straight incision is employed.

Careful observation and exploration of the tendinous cuff and the subacromial bursa should always be made.

Adhesions and peritendinitis of the biceps tendon are usually not seen until the tendon has been exposed by incision of the capsule and transverse humeral ligament; the tendon may then be visualized from its origin as far as its point of disappearance beneath the tendon of the pectoralis major. After exposure of the tendon, abduction of the arm will demonstrate whether the humerus slides freely along the tendon or whether it is bound by adhesions under the tendon of the pectoralis major. If such adhesions are present, the terminal portion of the tendon will buckle with abduction.

With an osteotome, a bed is made in the groove by elevating a portion of the floor from the outside inward. The tendon is roughened, and is sutured beneath this osteoperiosteal flap with heavy silk sutures (Fig. 7). The transverse humeral ligament is sewed down over the tendon and osteoperiosteal flap. The portion of the tendon lying above the transverse humeral ligament is resected. The shoulder is then put through a full range of motion. Very often, adhesions in the joint will be felt and heard to give. The wound is then closed without muscle sutures.

Objections to Other Sites of Fixation of the Tendon

Fixation to the short head of the biceps changes the course of the tendon and may produce pain, due to pulling on adhesions to the tendon under the pectoralis major insertion.

Fixation to either tuberosity of the humerus produces a prominence which will cause pain by abutting against the coraco-acromial ligament during elevation of the shoulder.

Fixation to the pectoralis major tendon produces pain by cross pull on that tendon.

Postoperative Care

The shoulder is kept in a Velpeau dressing for ten days; the stitches are then removed and the arm is put through a full range of motion, three times each week. Care is taken to avoid strain on the long head of the biceps tendon. At the end of six weeks the tendon should be well healed in its groove. The authors' experience in the treatment of lesions of the long head of the biceps muscle, according to the manner outlined, has been most gratifying. Loss of pain and the rapid return of function have been characteristic. The only residual disability is a slight loss in the power of abduction when the arm is in lateral rotation,—a loss which is scarcely appreciable to the patient and causes little inconvenience.

CONCLUSIONS

1. Lesions of the biceps tendon may be a cause of painful shoulder.

2. The normal anatomical mechanics of the biceps tendon are faulty. A supratubercular ridge or flat bicipital groove increases the mechanical difficulties.

3. An operation to fix the tendon in the bicipital groove and to remove that portion of the tendon above the groove relieves the symptoms caused by it and does not materially weaken the shoulder.

NOTE: The authors wish to thank Dr. John B. deC. M. Saunders, Professor of Anatomy at the University of California Medical School, for his help and advice, and for permission to study the humeri of the skeletons in the Anatomy Department of the University of California. Thanks are also due to the Department of Osteology at The Chicago Natural History Museum, for permitting a study of their primate humeri.

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DISCUSSION

DR. J. ALBERT KEY, ST. LOUIS, MISSOURI: This is a very interesting exposition of the anatomy and pathology of the long head of the biceps. I see shoulders with pain and tenderness over the biceps tendon and bicipital groove and treat them conservatively as bursitis, unless the condition is very acute or calcium accumulations are present. In such cases we remove most of the calcium, and expect relief. I believe that some of my failures, especially in the cases of longer duration, are due to neglect of the biceps tendon.

In the future I shall examine this tendon when I operate upon a frozen shoulder, shall perform the procedure outlined in this paper, and believe that my results will be better. However, in some of these frozen shoulders, the entire joint is involved. In two cases which I inspected after manipulation, the inferior portion of the capsule was torn either across or away from the glenoid. Apparently this does not do any great harm. The shoulder has great regenerative powers, as anyone knows who has treated conservatively the so-called tears of the supraspinatus. I have not sutured a supraspinatus tendon in twelve years, and I do not think I have had a shoulder that has been permanently disabled because I failed to suture the supraspinatus. Most of them get well in a few weeks if we leave them alone. As to the biceps tendon, I have not found a case that I could diagnose as slipping of the biceps, and consequently I have not operated. I believe that this paper will help me to diagnose the cases of painful tenosynovitis of the long head of the biceps which I have treated as chronic subdeltoid bursitis.

DR. ROBERT W. JOHNSON, BALTIMORE, MARYLAND: I want to compliment the authors on the presentation they have given of a lesion which I must have overlooked. I am not familiar with it. I wish Dr. Bennett were here, because he has had considerable experience with ballplayers, in whom tendon lesions of the shoulder are common. The biceps tendinitis is another pathological entity. As pointed out, it should not be confused with supraspinatus tears or bursal injuries. From this report, the operative procedure seems to be simple.

Since four cases were presented, I would like to ask the authors whether these four comprise their series, or whether these cases were selected to bring out a point. I think they selected four cases which differ from one another, in order to give us some idea of the picture.

DR. CHARLES O. BECHTOL (closing): It is true that most painful shoulders recover if given enough time. However, we feel that, in those cases of biceps peritendinitis where the patients do not recover promptly after conservative treatment, a much more rapid recovery with less economic loss can be offered by fastening the tendon into the groove. Our results in twenty-six such cases have been most satisfactory.

CONGENITAL PSEUDARTHROSIS

Follow-up Study after Massive Bone-Grafting *

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From the Campbell Clinic, Memphis

In 1941, a report was made as to the treatment of congenital pseudarthrosis by massive grafts, and a technique of dual bone-grafting was described [1]. It is the purpose of this paper to present a follow-up study of the cases reported at that time, and to add three additional cases of congenital pseudarthrosis of the tibia, treated with dual bone grafts.

In the 1941 report, bony union occurred in each patient who was treated with a massive bone graft. This resulted in an initial optimism which the subsequent findings do not substantiate. It has been found that refracture is prone to occur after bony union and that, when such a refracture does occur, the fracture site quickly reverts to a condition similar to that seen in the original pseudarthrosis. Union following a refracture is apparently as difficult to obtain as in the original non-union, with the exception that the patient is older and it is the consensus that, the older the child, the better the prognosis. The cause of the rapid absorption of bone about the fracture site following refracture is not known. In the patients reoperated upon for fractures following union, the tissue has been carefully examined for neurofibromata and none have been found.

In one of the case reports to be presented here, an "insufficiency" or so-called "march fracture" developed gradually at the original site of non-union, several years after bony union had occurred. The gradually developing "fracture" differed from a march fracture in that no callus developed about the fracture site. The insufficiency fracture weakened the bone to the extent that a minor trauma, even while the patient was wearing a brace, produced a complete fracture of the tibia.

Since refracture is prevalent, it is essential that adequate bracing be carried out following the bone graft until a new, well-developed medullary canal has formed across the fracture site, and until the tibia has reached sufficient size and strength to compare favorably with the normal one. This will usually require the use of a brace until the child is past puberty, which in actual practice means a period of from five to twelve years. It is the authors' opinion that the surgeon should watch for evidence of an early march fracture, recurrent sclerosis about the old fracture site, or narrowing of a previously reformed medullary canal. In the presence of one of these findings, or a combination, an operation to reinforce the area of former pseudarthrosis with supplementary grafts may be indicated before complete refracture of the tibia has had time to occur. This has not been done in any of our cases, but we believe that it may be an advisable procedure.

The first four case reports bring the original cases, reported in 1941, up to date. The last three cases are new.

CASE REPORTS

Case 1 (Campbell Clinic No. 15366). S. A., a white girl, was first seen on July 6, 1925, at the age of twenty-seven months. Anterior bowing of the leg was noticed during infancy, and fracture of the right tibia was first discovered at the age of fifteen months. The patient was placed in a cast for four weeks and in a brace for six months. The anterior and lateral bowing of the lower half of the tibia and fibula gradually increased. On admission, pseudarthrosis was demonstrated clinically and roentgenographically (Fig. 1-A). In addition to the pseudarthrosis of the tibia, a defect in the fibula was present. The history and roentgenographic findings indicated that the pseudarthrosis was probably secondary to a bone cyst.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 29, 1947.

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: Appearance of congenital pseudarthrosis before operation in a girl, twenty-seven months old.

Fig. 1-B: Appearance of the graft, one month and eleven days after operation.

Fig. 1-C: Appearance of the tibia, one year and three months after operation. Note that a small medullary canal has been re-established.

Fig. 1-D: Appearance of the tibia and fibula, twenty-two years after operation.

FIG. 1-D

On July 10, 1925, a massive onlay bone graft was done by Dr. Willis C. Campbell, who used a tibial graft from the mother. Circular wire loops were used to fix the transplant to the tibia. Cancellous bone was packed about the fracture site.

Roentgenograms, taken on August 21, showed the bone graft in place (Fig. 1-B). More than a year later, on October 9, 1926, roentgenograms (Fig. 1-C) showed solid union, with a medullary canal being re-established.

Valgus of 30 degrees of the right ankle and 25 degrees of the left ankle was present on May 20, 1937 (the valgus of the left ankle was due to congenital pseudarthrosis in the lower end of the left fibula). A supramalleolar osteotomy, to correct the valgus of the right ankle, was carried out on February 22, 1938. A similar operation was done on September 27, 1938, to correct the valgus deformity of the left ankle. Both osteotomies healed normally.

The patient was last seen on March 25, 1947, twenty-two years after the bone-grafting. She had no complaints relative to the pseudarthrosis. Figure 1-D shows the condition of the tibia on this date. Both legs were of equal length. There was approximately 20 degrees of valgus in both ankles, multiple café-au-lait spots, and two small subcutaneous masses, probably neurofibromata. The patient is a graduate nurse; she is married, has a child, and is doing her own housework.

CASE 2 (Campbell Clinic No. 41036). H. L., a white boy, was first seen on May 25, 1937, at the age of two and one-half years. False motion and angulation of the lower third of the right tibia and fibula were present at birth. One operation for correction of the deformity had been done at the age of nine months. On admission, there was anterior bowing of the leg, with free motion at the fracture site. Many café-au-lait spots were present. Roentgenograms showed pseudarthrosis of the tibia and fibula, with tapering ends and overriding of the bone fragments.

On June 21, 1937, the tendo achillis was lengthened and Hallock's operation [2] was performed. The multiple chips used were obtained from the ilium of the mother.

A year later, on July 25, 1938, roentgenograms showed absorption of chip grafts. Clinically, motion was present at the site of the pseudarthrosis.

A massive onlay graft was done on March 2, 1939; tibial bone from the mother was used, and cancellous bone was packed about the fracture site. Roentgenograms, taken on November 18, 1939, revealed bony

union at the fracture site, but there was still a tendency toward hemi-hourglass constriction, and the medullary canal had not reformed.

On September 26, 1940, roentgenograms showed evidence of a reforming medullary canal. A constriction was present at the fracture site. There was one inch of shortening of the affected extremity. On May 24, 1944, roentgenograms showed an apparent slight increase in sclerosis and narrowing of the medullary canal in the region of the old fracture site.

On October 24, 1944, the boy fell from a merry-go-round and sustained a fracture of the tibia at the original site of the congenital pseudarthrosis. For the previous two and one-half years, against medical advice, the patient had walked, run, and played without using a brace.

Roentgenograms, two and one-half months after refracture (January 16, 1945) showed definite absorption of the bone ends, despite continuous immobilization in a cast.

A dual bone graft was performed on June 4, 1945, by Dr. R. A. Knight, the opposite tibia being used as a donor site. Incomplete union was present on February 18, 1946.

By March 12, 1947, there was only one-quarter of an inch of shortening of the affected extremity. However, actual tibial shortening was three-quarters of an inch; a longer femur compensated for some of the tibial shortening. The boy was still wearing a brace. Roentgenograms showed solid bony union.

Case 3 (Campbell Clinic No. 46921). W. J. W., a white girl, was first seen on July 19, 1939, at the age of five years. Fracture in the middle third of the left tibia had been present at birth. A bone graft, the fibula from the other leg being used, had been done at the age of one year. This was followed by cast immobilization for three years. On admission, there was anterior and medial bowing of the tibia and definite non-union, both clinically and roentgenographically. The left lower extremity was three-eighths of an inch shorter than the right.

Three days later, on July 22, dual bone grafts were applied, tibial bone from the father being used. Cancellous bone was packed about the fracture site and between the grafts. The screws were removed on December 27, 1940. Fifteen degrees of valgus of the ankle was present. The affected leg was three-eighths of an inch longer than the normal one. Roentgenograms showed bony union.

The patient was transferred from the authors' care. However, roentgenograms, taken elsewhere on October 3, 1941, showed union, but the tibia was still slender.

On February 20, 1942, roentgenograms, taken elsewhere, showed bony union with re-establishment of the medullary canal. The bone gradually became hypertrophied with use, but the tibia was still slender. This patient has moved to another section of the country and efforts to trace her since 1942 have failed.

Case 4 (Campbell Clinic No. 35657). R. L. D., a white boy, was first seen on March 25, 1935, at the age of three years. From the history, it was learned that the lower extremities had been apparently normal at birth. As the child grew, his parents noted a gradual anterior and lateral bowing of the left tibia. With increase in the deformity, a limp developed.

Four days before admission, while walking, the patient turned his ankle and noticed immediate pain in the lower third of the leg. After this, he refused to bear weight on the limb. Roentgenograms revealed a fracture at the juncture of the middle and lower thirds of the tibia, through a bone cyst. A large cystic area was also evident in the upper third of the tibia.

For the next four years, the leg was intermittently immobilized in plaster and supported by a brace, but non-union persisted. Roentgenograms, taken on September 20, 1939, showed a minimal amount of callus at the fracture site, with a marked increase in anterior tibial angulation. The bone cyst in the upper third of the tibia was decreasing markedly in size (Fig. 2-A).

A dual onlay bone graft was applied on September 23, 1939, tibial grafts from the mother being used. Roentgenograms, taken on January 26, 1940, showed beginning union of the grafts and obliteration of the fracture site. The alignment was satisfactory (Fig. 2-B).

By August 14, 1940, the leg was clinically solid. It had been immobilized in a cast for six months after operation and then supported by a brace. Roentgenograms showed that the screws had been removed; good bony alignment was present; the fracture line had been obliterated; and a good medullary canal had reappeared. The affected leg was one-half inch longer than the normal one.

The patient wore a brace for three years after operation. When seen on July 14, 1943, the foot on the affected leg was one inch shorter than the foot on the sound side. Roentgenograms disclosed no changes, except that the cyst had nearly disappeared.

When last seen on January 22, 1947, seven years and four months after the dual bone-grafting, the patient was carrying out normal activities for his age; the affected lower extremity was three-fourths of an inch longer than the sound one. A calcaneovalgus deformity of the left foot was present, associated with moderate cavus. Café-au-lait spots were noted on the abdomen and buttocks. Roentgenograms showed a sound tibia (Fig. 2-C).

Case 5 (Campbell Clinic No. 41224). J. E., a white boy, struck his left leg against a table and presumably sustained a fracture at thirteen months of age. However, the leg was thought to have been "crooked" before the fracture. The limb was immobilized in a cast for eight months, after which braces were used. He

was first brought to the Clinic for treatment at the age of five years. At this time the pseudarthrosis was still present and roentgenograms (Fig. 3-A) showed the non-union with marked narrowing and overriding of the bone ends.

On September 15, 1941, a dual bone graft was applied, tibial bone from the foster father being used. Figure 3-B showed the dual graft, three weeks after the operation. Cast immobilization was continued for five and one-half months, after which a brace was used.

By December 1, 1941, the leg was clinically solid. Weight-bearing in the brace was started on March 21, 1942. Roentgenograms showed obliteration of the fracture line and union of the grafts to both tibial fragments, particularly the proximal one. On July 2, 1942, the screws were removed. Roentgenograms (Fig. 3-C) showed complete union of the dual grafts to the tibial fragments, and obliteration of the fracture line. Moderate anterior angulation was present.

Roentgenograms, taken on August 26, 1943, showed a fairly well-developed medullary canal. The anterior bowing and ankle valgus had increased somewhat. The affected extremity was three-quarters of an inch shorter than the normal, but the femur on the affected side was longer.

When seen on July 28, 1944, the patient was continuing normal activities in a brace, without difficulty. Roentgenograms continued to show a good medullary canal (Fig. 3-D).

Serial roentgenograms, beginning on February 10, 1945, showed the progressive development of an "insufficiency" type of fracture, without callus formation about the advancing osseous defect (Figs. 3-E through 3-I). An associated sclerosis of the bone appeared about the site of the former pseudarthrosis, with gradual filling in and narrowing of the medullary canal. A complete fracture occurred as the result of a misstep, while the patient was going down steps on August 14, 1946, approximately five years after the bone-grafting (Fig. 3-J). He was wearing a brace at the time the fracture occurred.

A below-the-knee amputation was performed on September 2, 1946. At that time the affected tibia was one and one-half inches shorter than the sound one. Roentgenograms of the specimen (Fig. 3-K) showed marked absorption of bone about the fracture site; this developed in a period of nineteen days, during which the leg was immobilized in plaster. At the present time, the patient is walking well with a prosthesis.

Case 6 (Campbell Clinic No. 58879). R. K., a white boy, was first seen on March 2, 1943, at the age of seven and one-half years. Anterior bowing of the right leg had been noted at birth. A roentgenogram, taken on November 20, 1935, showed increased tibial and fibular bowing; the diameters of the bones remained normal.

Roentgenograms on April 27, 1936, showed a completely fractured fibula with absorption of bone ends, a decrease in the medullary canal of the tibia, and increasing sclerosis. On February 12, 1937, roentgenograms revealed complete obliteration of the medullary canal in the tibia, with increased sclerosis at the site of angulation. Casts were used for intermittent immobilization from the age of eight months until two years, at which time a corrective osteotomy of the tibia was done. Roentgenograms taken on July 29, 1938, and September 18, 1939, showed persistent tibial and fibular non-union.

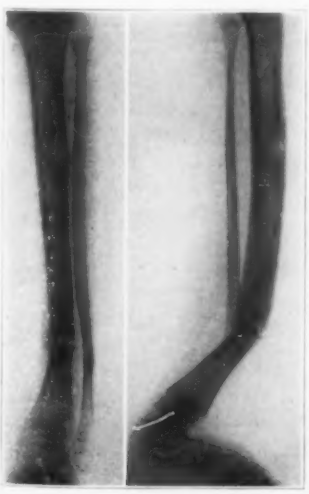

Fig. 2-A

Fig. 2-B

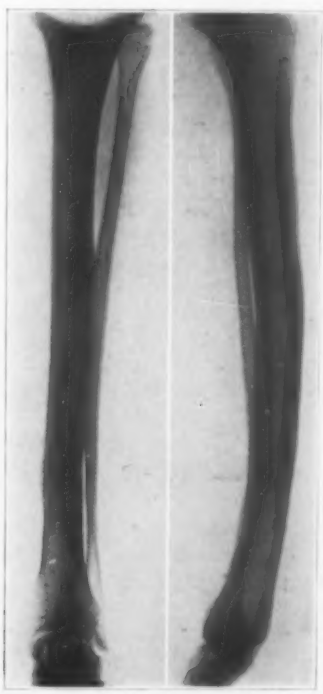

Fig. 2-C

Fig. 2-A: Appearance of the pseudarthrosis before operation.
Fig. 2-B: Appearance of the tibia four months after dual bone-grafting.
Fig. 2-C: Appearance of the tibia seven years and four months after dual bone-grafting.

FIG. 3-A

FIG. 3-B

FIG. 3-C

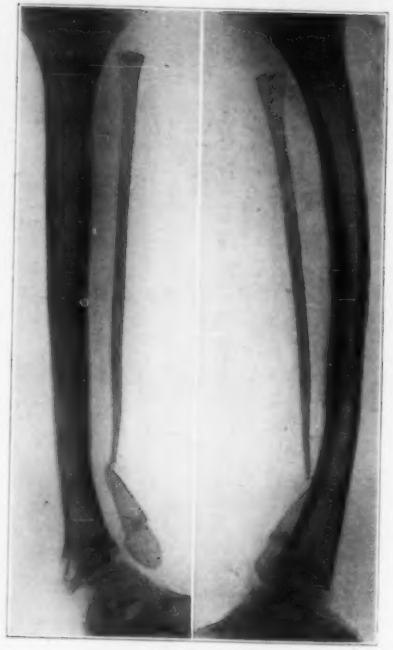

FIG. 3-D

Fig. 3-A: Appearance of the pseudarthrosis before bone-grafting in a boy, aged five.
Fig. 3-B: Appearance of tibia three weeks after application of a dual bone graft. Note proximity of the lower end of grafts to epiphyseal line.
Fig. 3-C: Appearance of tibia nine months after dual bone graft. Note displacement of the lower ends of grafts from the epiphyseal line, due to rapid growth. This was probably in excess of normal, because of stimulation of the epiphyseal line after operation.
Fig. 3-D: Two years and ten months after dual bone graft. There is bony union with re-establishment of medullary canal.

Fig. 3-E: Lateral view of tibia, three years and five months after dual bone graft, shows sclerosis about the fracture site with beginning occlusion of the medullary canal and the beginning of an "insufficiency fracture" in the posterior cortex of the tibia.
Fig. 3-F: Three years and eight months after grafting.
Fig. 3-G: Four years after grafting.
Fig. 3-H: Four years and four months after grafting.

FIG. 3-E

FIG. 3-F

FIG. 3-G

FIG. 3-H

FIG. 3-I

FIG. 3-J

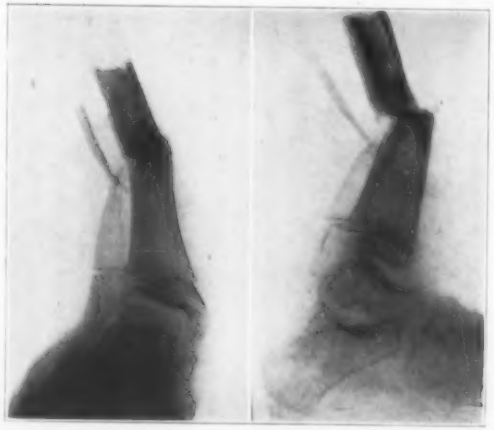

FIG. 3-K

Fig. 3-I: Four years and eight months after operation. Figs. 3-E to 3-H, inclusive, show a gradual advance of the insufficiency fracture, slight increase in angulation at the fracture site and gradual increase in the sclerosis about the fracture site, and obliteration of the medullary canal.

Fig. 3-J: Four years and eleven months after grafting, the insufficiency fracture was completed, as a result of minor trauma.

Fig. 3-K: Roentgenograms of the amputated extremity, nineteen days after completion of the fracture. Note absorption about the fracture site, which occurred despite cast immobilization.

When the boy was four and one-half years of age, an inlay graft was done with the use of bone from the sound tibia. Union did not occur. The leg was supported in a brace until the time of admission to the Clinic. On admission, the pseudarthrosis was evident from clinical and roentgenographic examination. The affected extremity was two and one-half inches shorter than the sound one. Many café-au-lait spots were noted and one tumor (probably a neurofibroma), measuring 1.5 centimeters in diameter, was present on the sole of the left foot.

On March 3, 1943, the day after admission, a dual bone graft was applied; tibial bone from the mother was used. Roentgenograms, taken on April 14, showed the graft in place. Cast immobilization was discontinued on June 4, and a brace was applied. The fracture was clinically solid. On September 11, roentgenograms showed union of the grafts to both tibial fragments. Six days later, on September 17, pain developed in the leg while the boy was walking with a brace. Roentgenograms revealed an incomplete fracture of the tibia, along the course of the proximal screw in the distal fragment. The child was extremely active, but no definite trauma was recalled. By October 13, rapid absorption of the bone ends was evident, even though the leg was immobilized in a cast. Roentgenograms, taken on December 31, showed further increase in the absorption about the fracture site, with narrowing of the bone ends.

With the use of tibial and fibular bone from the father, dual grafting was performed on January 4, 1944; a tibial graft was used posteriorly and a step-cut fibular graft anteriorly, reinforced by two short cortical fibular grafts laterally. Cancellous bone was used to pack around the fracture site. At operation, a fracture occurred through the osteoporotic tibia, just above the ankle at the lower level of the grafts. On October 16, roentgenograms showed union of the grafts to both tibial fragments, with fairly complete obliteration of the fracture line. The supramalleolar fracture had united, with anterior angulation.

The patient has not been seen since October 1944, but, through the courtesy of Dr. Leo Mayer, his brace immobilization has been continued and reports of periodic follow-up roentgenograms have been received. On November 14, 1944, sclerosis at the old fracture site was decreasing. A medullary canal was just beginning to reform. Roentgenograms, taken on October 3, 1945, revealed re-establishment of the medullary canal. The diameter of the tibia was definitely wider at the site of former pseudarthrosis. On December 3, 1946, no definite change in the roentgenograms was noted, except for gradual lessening of the anterior tibial angulation.

Case 7 (Campbell Clinic No. 62253). V. L. S., a white girl, was first seen on February 2, 1944, at the age of eight years. From roentgenograms which were brought in and from her history, the following information was obtained: A deformity of the right leg had been noticed since nine months of age, and had been treated intermittently by casts and braces. Roentgenograms taken on December 22, 1937, showed a double fracture of the tibia and a single fracture of the fibula at the juncture of the middle and lower thirds. Roentgenograms taken on February 1, 1943, showed marked posteromedial angulation of the leg, with narrowing and tapering of the bone ends. On first admission, there was clinical evidence of non-union with a marked valgus deformity of the lower third of the leg. One questionable café-au-lait spot was present on the chest.

A dual bone graft was done on February 8, 1944, paternal fibula being used. Bone chips were packed about the fracture site. Roentgenograms on September 5 showed union of the grafts to the proximal and distal tibial fragments. The fracture line was still present.

In spite of continued cast immobilization, absorption had occurred at the fracture site by November 24, 1945, with recurrence of the deformity. Two days later, on November 26, a second dual bone graft was performed by Dr. R. A. Knight, bone from the opposite tibia being used. The patient was still wearing a cast on June 1, 1946, when she was transferred from our care.

Roentgenograms taken elsewhere on October 19, 1946, showed union, but the medullary canal had not been re-established. On May 16, 1947, roentgenograms showed bony union with amalgamation of the grafts with the tibia. The diameter of the tibia was definitely increased.

DISCUSSION OF UNSUCCESSFUL CASES AFTER THE INITIAL MASSIVE GRAFT

Of the seven cases reported in this paper, four patients required subsequent operative procedures after the initial massive bone graft.

Case 2. Excellent union occurred, but factors predisposing to refracture were an abnormal curve in the tibia, sclerosis about the site of the former pseudarthrosis with narrowing of the medullary canal, and a tibia smaller than normal. This patient, against medical advice, had been carrying out normal activities for a boy of his age for two years, without support. The fracture resulted from definite trauma,—he fell from a merry-go-round. This fracture probably would not have occurred had the extremity been supported adequately. This emphasizes the fact that these patients should wear a brace until puberty, or until the size and texture of the tibia are essentially the same as on the sound side. Satisfactory union was obtained after a second graft was applied.

Case 5. Following the original dual bone graft, bony union occurred and a medullary canal was re-established. Subsequently, an "insufficiency fracture" developed, beginning on the posterior aspect of the tibia at the site of the original non-union. This was converted into a complete fracture by a minor trauma, occurring while the patient was wearing a brace. Following the fracture, the problem was thoroughly discussed with the parents. After taking into consideration the shortening, the calcaneovalgus position of the foot, the possibility of failure or refracture following a second graft, and the function of an artificial limb as compared with that which could be expected from the extremity after a successful second graft, the parents preferred an amputation.

Case 6. In this patient, bony union occurred after the first dual bone graft. A crack developed along the upper screw in the distal fragment. Rapid absorption of the sclerotic bone in this area occurred. This child was obese and the thighs were unusually large in comparison with the legs, making cast immobilization difficult. With these factors in mind and in view of the possibility of failure of a second graft, amputation was suggested to the parents. They, however, preferred a second bone graft; this was done and to date has proved successful.

Case 7. The pseudarthrosis failed to progress to union after the original dual bone graft. In this case, a split fibular graft, taken from the father, was used. This material possibly is inferior for grafting, as compared with tibial grafts. It was taken in the desire to spare the tibia of the donor, as the father was a farmer and needed to return to his plowing at an early date. Union followed the second dual graft, in which autogenous tibial grafts were used.

DISCUSSION OF SUCCESSFUL CASES AFTER THE INITIAL MASSIVE GRAFT

Case 1. This patient has a successful result twenty-two years after a massive onlay graft, performed at the age of twenty-seven months. No shortening has developed in the extremity. This case illustrates the advantage of early grafting.

Case 3. When last heard from, this patient had bony union and a medullary canal had been re-established. The tibia is still small and refracture may easily occur, if adequate bracing is not maintained.

Case 4. This patient obtained solid union after the first dual bone graft, and has not worn a brace for two years. However, he is an exception to the rule, as the fracture occurred through a bone cyst. The ends of the bone were not tapered, and a tibia of approximately normal size developed in a short time.

SUGGESTIONS FOR TREATMENT

The optimal time for bone-grafting has been discussed in the literature. It is the consensus that the older the patient, the greater the probability of union; and that union is obtained with greater ease after puberty. However, the longer the operation is delayed, the more shortening will occur; the leg will be poorly developed; and the deformity, due to anterior bowing of the leg and calcaneovalgus of the foot, will be greater. Case 1 of this series emphasizes the advantage of early successful operations. It is the authors' opinion that the patient should be operated upon as early as practicable, — that is, from three to five years of age.

At operation, the surgeon should remember that the bone is small and osteoporotic. The dual graft forms a "bone clamp"; consequently, it is easy to fracture the osteoporotic bone just above the ankle, at the lower end of the graft. This occurred in two of the patients reported in this series; both fractures united promptly. In Case 1, a supramalleolar osteotomy was done on both tibiae to correct the valgus of the ankles; each united in normal time. This emphasizes the opinion that the cause for non-union in congenital pseudarthrosis is a localized factor and does not involve the other bones of the body, nor even the same bone, a few centimeters from the pathological area. The screws should be placed

as far from the area of pseudarthrosis as is practicable, as their presence is apt to predispose to refracture. The technique for the application of a dual bone graft and the advantages of this procedure are outlined in the article published in 1941 by the senior author.

Grafts taken from a bone bank would be ideal for this procedure, as adequate autogenous bone is usually not available for massive bone-grafting in children. The hospitalization of a second member of the family as a bone donor entails additional expense. There is also the hazard of weakening the tibia of the donor, and the possibility of fracture if the tibia is inadequately protected. After sufficient bone has been removed for a dual graft, the donor is required to wear a long leg brace for four to six months.

A long leg cast is applied after the operation and, in small or fat children, a spica may be necessary to ensure adequate immobilization. The immediate postoperative cast is usually changed in approximately ten days, and a snug, well-fitting one is applied. The cast should then be changed often enough to ensure adequate, continuous immobilization until union is apparent in the roentgenograms. This usually requires four to six months. Following cast immobilization, a leather lacer brace is used until a well-developed medullary canal has formed and the tibia is essentially the same size as the normal one. This will usually require the use of a brace until the time of puberty. The type of brace advocated by Kite, in which the leather sleeve laces posteriorly, is superior to one laced down the front of the leg; a solid, well-molded piece of leather on the anterior surface of the leg gives better support to the tibia, which usually has a tendency to become angulated in that direction.

Three types of patients with congenital pseudarthrosis are recognized,—those born with a defect in the tibia; those with fractures developing in a congenital cyst of the tibia; and those born with congenital bowing of the tibia, in whom the bone is small and sclerotic and the medullary canal is diminished in size or absent. In the third type, the tibia usually breaks as the result of minor trauma. Following the fracture, absorption occurs and a typical pseudarthrosis results. In a patient of the third type, osteotomy to correct the bowing of the tibia should not be done, as non-union will develop and, in the minds of the parents, the surgeon will be held responsible for the subsequent train of unfortunate events. This is well illustrated by Case 6 in this series.

The prognosis for fractures developing in congenital cysts is probably more favorable; the bone is better suited mechanically for grafting, because the ends of the bone are not narrowed and pointed, as in the other two types. Also, the medullary canal in both fragments is larger and consequently easier to expose and open, as illustrated in Case 4.

The choice between amputation and bone-grafting may be a difficult one. It is necessary to compare the usefulness of an artificial limb with that of the extremity which can reasonably be expected after a successful bone graft, rather than with a normal leg. An expected shortening in excess of three inches, a considerable residual deformity, such as anterior bowing of the tibia and pes calcaneovalgus, and the constant possibility of refracture of a small, weak tibia may be indications for an amputation. On the other hand, there is no question that some patients are better with a bone graft. The patient presented as Case 1 is now twenty-four years of age, is a registered nurse, married, has a child, and is doing her own housework,—accomplishments difficult to attain with an artificial leg.

CONCLUSIONS

1. In the seven cases reported, ten massive bone grafts have been used. Bony union followed all but one of these operations. This indicates that union can be anticipated in the majority of cases after this procedure. However, in three instances, refracture occurred following union.

2. In one patient, amputation was done after refracture. Bony union has been present following the second bone-graft operation for one and one-half years, two years,

and three and one-half years, respectively. Union has persisted after the first massive graft for two and one-half, seven and one-half, and twenty-two years, respectively.

3. A refracture may be preceded by an increase in sclerosis about the fracture site, narrowing of a previously reformed medullary canal, or an insufficiency fracture. Routine follow-up roentgenograms should be made at six-month intervals to determine if any of these factors are developing, and, if so, surgical intervention may be indicated before a complete refracture occurs.

4. Following refracture, rapid absorption of the bone occurs, and the fracture site soon reverts to a condition simulating that seen in the original congenital pseudarthrosis.

5. It is probably unwise to draw conclusions as to end results in this condition until the patients have become young adults or at least are past puberty. In this series only Case 1 can be considered as having a good end result, according to these criteria.

6. At the termination of cast immobilization, adequate bracing must be maintained until a new medullary canal has developed and the consistency and size of the tibia compare favorably with the normal.

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DISCUSSION

Dr. Halford Hallock, New York, N. Y.: From this and other studies, it is evident that certain factors are present in congenital pseudarthrosis, which prevent the growth of bone or interfere with its integrity after union has been obtained. These are probably circulatory and, in some patients, related to neurofibromatosis. Scarring from previous unsuccessful operations undoubtedly also plays a part. These factors must be considered in any reconstruction procedure, and must constantly be kept in mind during the long period of convalescence that Dr. Boyd has emphasized is necessary for the assurance of a long-term successful result. The combined method of small bone transplants and rigidly fixed dual grafts, which Dr. Boyd employs, physiologically would appear to be the most effective means of dealing with pseudarthrosis. This is borne out by the high degree of early union. Small bone transplants are rehabilitated readily, and the bone grafts with internal fixation provide the immobilization necessary for union. Good bone above and below is necessary for contact with grafts. If this is not possible, or if extensive scarring is present anteriorly, the posterior surface of the tibia can be employed as a site for grafting. Neurofibromatous tissue should be removed, because it may interfere with union or may later be responsible for the recurrence of pseudarthrosis. I agree with Dr. Boyd that if bone sclerosis should increase or an "insufficiency" fracture should develop, after union has been secured, reoperation would be advisable. This should be along the line of reinforcing bone repair and increasing local circulation. Although a refracture spontaneously united in one of our patients at the New York Orthopaedic Hospital, in one it did not. The second patient for several years had showed evidence of an insufficiency fracture at the site of previous pseudarthrosis, and I am sure that reoperation at that time would have prevented non-union. In those patients in whom this operation may fail or in whom conditions are such that a good result cannot be expected, it must not be forgotten that transplantation of the fibula, if feasible, may be of service and may make amputation unnecessary.

Dr. Rex L. Diveley, Kansas City, Missouri: We are indebted to Dr. Boyd for calling to our attention this most difficult condition and for advancing a method which, according to his report, bids fair to being a solution.

When I was asked to discuss this paper, we reviewed our cases, and, of the seven cases followed, we failed to find one with a bony union following operative procedures. Five had had amputations, and the remaining two are considering advised amputations. We have always used the single massive graft or the fibular transplant. After listening to this report, we may feel that the dual graft is the answer.

My personal observations may be summed up as follows: If the pseudarthrosis is complicated by deformity of the foot, ankle, or knee, it would seem advisable to suggest amputation. If the congenital pseudarthrosis is uncomplicated, with not too great a deformity at the point of the arthrosis, the dual bone graft should be tried, according to the technique outlined by Dr. Boyd.

PERITENDINOUS FIBROSIS OF THE DORSUM OF THE HAND

BY MAJOR ROBERT E. VAN DEMARK, LIEUTENANT COLONEL JOHN D. KOUCKY, AND LIEUTENANT COLONEL FREDERICK J. FISCHER

Medical Corps, Army of the United States

In contrast to the usual traumatic tenosynovitis which responds to treatment, a painful, persistent, peculiarly hard swelling, localized over the dorsal metacarpal area and absent in the palm, may follow a blow to the back of the hand. Little attention has been given in the American literature to this condition, the typical etiology and early physical findings of which were originally described by Henri Secrétan in 1901. (It has been called dorsal oedema of Secrétan, and traumatic hard oedema of the dorsum of the hand.) In 1943, Watson-Jones stated that the pathology of this intractable condition was not well understood. Iselin, in his monograph on the hand, has commented on its rarity, stating that he has never seen a case; Cutler and Bunnell in their treatises do not specifically mention the syndrome, apparently because of its infrequency.

An unusual opportunity was afforded to diagnose, observe, and obtain biopsy specimens from two such cases during a recent period of military service. The pathological findings, similar in the two cases and officially confirmed microscopically in the second case at the Army Medical Museum, present certain typical features and establish a fundamental basis for the symptomatology, prognosis, and treatment.

CASE REPORTS

CASE 1. A negro male, aged twenty-eight, was admitted to Bruns General Hospital, Santa Fe, New Mexico, on December 8, 1943, with a transfer diagnosis of synovitis of the extensor tendons of the right forearm and purpura hemorrhagica.

In June 1943, the patient was struck on the dorsum of the right hand by the flat side of a broken rotary-saw blade. Although the skin was not broken, severe pain and swelling occurred immediately. Roentgenographic examination showed no evidence of a fractured metacarpal, which was at first thought to be present. The swelling on the dorsum of the hand extended into the fingers and persisted for three months before subsiding. While in a hospital overseas, the patient had suffered from intermittent bleeding of a variable degree for a five-day period, from the site of an extracted tooth. There was no previous history of unusual or prolonged bleeding.

Physical examination on admission disclosed that the right hand showed a slight thickening of the peritendinous tissue on its dorsum. Due to a painful "checkrein" effect on the extensor tendons of the medial four digits, the patient could not make a tight fist. Motions of the right thumb were free. Routine examination was otherwise not remarkable.

An exhaustive study by the medical staff failed to confirm the diagnosis of purpura hemorrhagica or to disclose any other hemorrhagic disease. While the patient was helping with the routine work about the ward, following admission to Bruns General Hospital, and in the absence of any distinct trauma, severe swelling developed on the dorsum of the right hand. The character of the swelling was firm and non-pitting; peripherally a milder oedema extended into the fingers and borders of the hand, where it gradually faded. Motions of the fingers were painful, and flexion of the fingers was severely limited by pain on the dorsum of the hand.

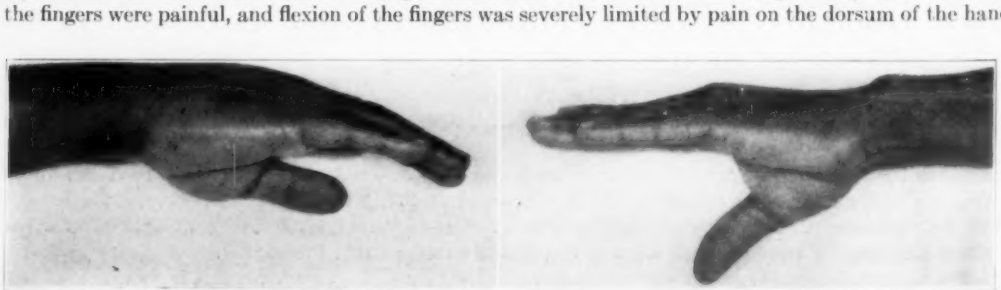

FIG. 1-A

FIG. 1-B

Case 1. Right (Fig. 1-A) and left (Fig. 1-B) hands, showing the marked swelling of the dorsum of the right hand, with milder swelling of the fingers and border of the palm.

FIG. 1-C

Roentgenograms of the right and left hands, thirteen months after the original injury to the right hand. Note absence of bone atrophy or spotty decalcification.

Casts were successively applied to the hand in the position of optimal function; the severe swelling subsided in five months, leaving only a slight thickening. After an additional two months of inactivity, the patient was allowed to use the affected hand. Swelling and pain recurred (Figs. 1-A and 1-B) and exploration was decided upon.

FIG. 1-D

Right hand at completion of stay in hospital. Compare with Fig. 1-A.

Allergy examination, including skin tests for foods, pollens, and epidermals (fur, feathers, and dander), was negative. A neuropsychiatric examination was negative. Blood-chemistry studies revealed no abnormal values of the icterus index, van den Bergh direct and indirect reactions, non-protein nitrogen, urea nitrogen, uric acid, creatinine, sugar, chlorides, cholesterol, phosphorus, calcium, phosphatase, carbon dioxide combining power, total protein, and albumin-globulin ratio. The phenolsulphonphthalein test, urea clearance, urine concentration, and bromsulphalein tests were within normal ranges. The basal metabolic rate was plus 7. The injection of 0.5 milligram of histamine diphosphate subcutaneously, during the period of quiescence, produced a local swelling which had largely disappeared in four days. The Mantoux skin test was plus 2. Calcium oxalate crystals were present in the urine on several occasions when the patient was placed on a high-oxalate diet. Quantitative urinary-oxalate examination, while not strictly accurate because of technical difficulties, showed a consistently high excretion over a three-month period, as compared with two controls. No exacerbation of symptoms resulted, as far as could be noted, from this diet. No evidence of acid-fast organisms was found in the urinary sediment. Repeated examination of the blood revealed no abnormalities of the blood elements or disturbances in the clotting and bleeding mechanisms. The Kahn test was negative.

As was true in the original case reports of Secrétan, no abnormalities of the bones and joints of the right hand were shown by roentgenographic examination at any time. Thirteen months after the injury (Fig. 1-C) there was no disuse atrophy, although this may appear late in the disease. No abnormalities were found on examination of the lungs.

At operation, a pneumatic tourniquet having been applied, a transverse incision was made on the dorsum

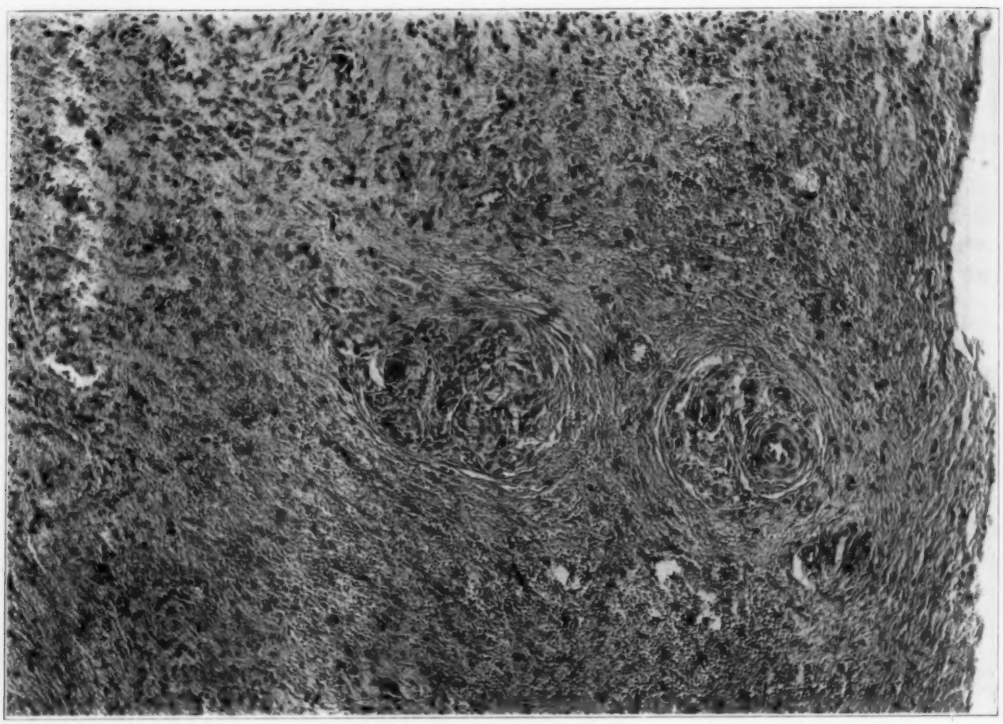

FIG. 1-E

Fibrous peritendinous tissue of collagenous character with numerous small and medium-sized thick-walled vessels; stained with hematoxylin and eosin (×92).

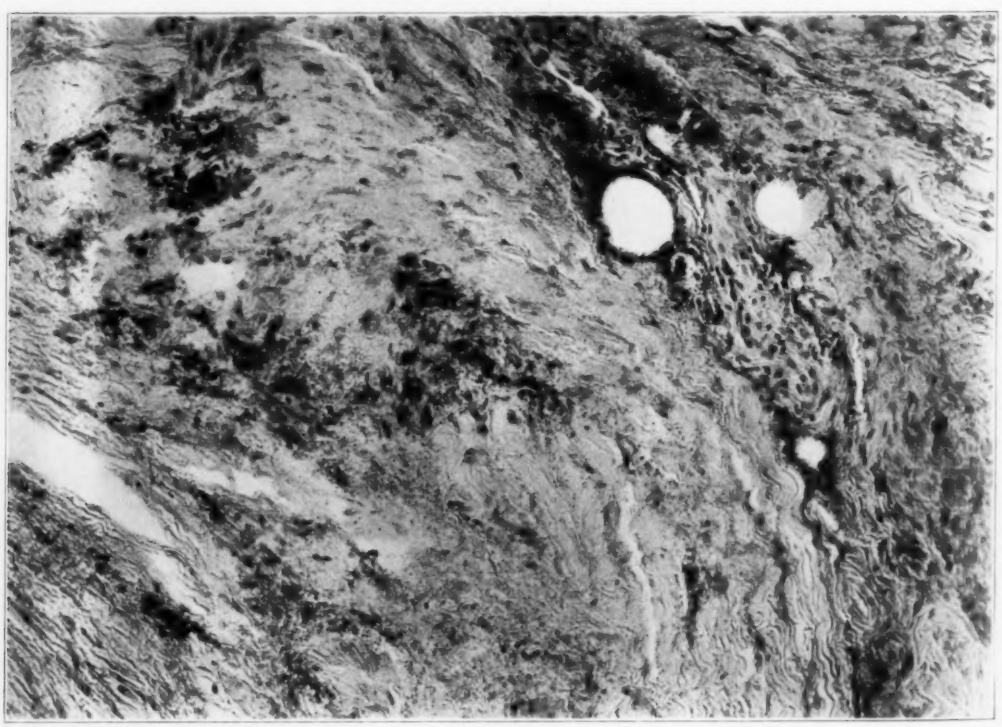

FIG. 1-F

Note the dark-staining intracellular and extracellular iron pigment (Prussian-blue stain) (×184).

of the hand, exposing the subcutaneous tissue; this was grossly fibrotic and entirely covered the extensor tendons of the fingers. The tissue had a light yellow tint, suggestive of previous hemorrhage, and measured approximately 0.5 centimeter in thickness, when incised down to the extensor tendon of the ring finger, which it surrounded. A specimen of the subcutaneous tissue was taken for biopsy. Exploration of the fibrotic mass laterally revealed a hematoma, consisting of clotted blood and serum, deep in the layer of fibrous tissue and superficial to the tendons. The hematoma was evacuated; its volume was approximately six cubic centimeters. The clots were forwarded to the laboratory with the biopsy specimen. A culture of the wound was taken before closure, and a firm pressure dressing was applied.

The wound healed by first intention, despite culture findings of *Staphylococcus albus*, which was probably a contaminant. The swelling entirely disappeared from the fingers and borders of the hand after removal of the pressure dressing, on the fifth postoperative day. At that time the swelling on the dorsum of the hand was diminished approximately 60 per cent. Because of previous reports of delayed wound healing, the sutures in the skin were not removed until the sixteenth postoperative day. Two weeks later the scar broke open at the central portion of the incision, despite adequate care and protection, but promptly healed. The hand was protected in an aluminum splint, and function was gradually resumed. Shortly before discharge of the patient from the Hospital (on November 27, 1944), only a slight thickening was evident on the dorsum of the hand (Fig. 1-D); flexion at the metacarpophalangeal joints was limited almost 50 per cent. In a letter dated March 25, 1945, the patient stated that he was working part time as a laborer and had only slight discomfort in the hand. The authors have since heard indirectly that swelling recurred, but have been unable to get in touch with the patient.

Microscopic Examination of Pathological Specimens: In sections stained with hematoxylin and eosin (Fig. 1-E), the fibrous subcutaneous tissue consisted of dense interlacing bands of collagenous tissue with numerous medium-sized and small thick-walled blood vessels. In the interstices of the collagenous tissue was an intracellular brown pigment, having the characteristic staining reaction for iron (Prussian-blue stain) (Fig. 1-F). Abundant iron pigment was also found lying free between the fiber bundles. Some of the collagenous tissue had undergone hyalinization. The clots from the hematoma were of recent origin.

Case 2. A white male, aged thirty, was admitted to the Regional Hospital, Camp Joseph T. Robinson, Arkansas, on December 29, 1945, because of a recurrent painful swelling on the dorsum of the left hand. On November 12, 1945, he had slipped on the wet ground, striking the dorsum of his left hand against a tent pole. Localized swelling immediately developed at the site of injury on the dorsum of the hand. After rest the swelling subsided somewhat, only to recur with extreme flexion of the fingers. A roentgenogram had revealed no fracture. The past history was essentially negative.

Physical examination at the time of admission to the Hospital revealed a hard, non-pitting oedema on the dorsum of the left hand, most marked in the region of the distal third of the metacarpal shaft (Figs. 2-A and 2-B). The skin was not discolored and showed no evidence of trauma; no temperature changes were evident. A moderate degree of hypo-aesthesia was present over the dorsal surface of the proximal phalanges of the left fingers. Motion of the thumb was free, but flexion of the fingers was limited because of pain on the dorsum of the affected hand. Roentgenographic examination was entirely negative (Fig. 2-C). Multiple microscopic examinations of the urine revealed oxalate crystals on only one occasion. The basal metabolic rate was plus 13. Blood examinations, including bleeding time, prothrombin time, clotting time, sedimentation rate, reticulocyte count, hemoglobin, leukocyte count, and differential, were normal. The Kahn test was negative. Blood-chemistry examinations were limited by technical facilities; the blood urea nitrogen, sugar, cholesterol, and icterus index were all found to be within normal limits. A neuropsychiatric examination disclosed symptoms in the left arm, which, to the consultant, were suggestive of hysteria. A consultation revealed no history or evidence of allergy.

On the evening of January 8, 1946, the patient was requested to flex his fingers to the point of pain, in an attempt to increase the swelling; no marked enlargement occurred. On the following morning, January 9, exploration and biopsy of the left hand were performed under general anaesthesia, a pneumatic tourniquet being used on the affected extremity. A small fibrous-tissue plaque, slightly yellow in color, was found over the distal metacarpal area, involving the extensor tendon of the middle finger. The adherent plaque moved with extension and flexion of the finger. On the radial side of the extensor tendon and within the plaque was a small area of granulation tissue, approximately three millimeters in diameter, with evidence of fresh hemorrhage. A small synovial-like sac was found, extending under the plaque and tendon on the ulnar border between the metacarpal bone and the involved tendon. Multiple specimens were taken for biopsy, including the fibrous plaque, the region of the granulation tissue, and a small dorsal peripheral portion of the extensor tendon with its adherent fibrous tissue. The tendon was then freed, and the wound was closed with interrupted sutures.

The wound healed by first intention; the sutures were removed on the fourteenth postoperative day. Three weeks after operation the patient was transferred elsewhere; his subsequent course is unknown.

Microscopic examination of sections of the plaque, stained with hematoxylin and eosin, revealed the presence of collagenous tissue and young fibrous tissue (Fig. 2-D). Prussian-blue stain demonstrated the

presence of iron pigment, both intracellularly and extracellularly (Fig. 2-E). A small area of iron pigment was noted within the tendon. Free red blood cells were observed in the area of recent hemorrhage. The peripheral portion of the tendon was infiltrated with fibroblasts (Fig. 2-F). The diagnosis, as reported by the Pathology Section at this Hospital and officially confirmed at the Army and Navy General Hospital and the Army Medical Museum, was: "Subcutaneous tissue, spontaneous hemorrhage; subcutaneous tissue, fibrosis with collagen infiltration; subcutaneous tissue, hemosiderosis and peritendinous fibroblastic infiltration".

PATHOGENESIS AS SUGGESTED BY PATHOLOGICAL AND ANATOMICAL FINDINGS

The presence of abundant iron pigment in the fibrous tissue, both intracellularly and extracellularly, indicates that the peritendinous fibrosis was a reaction to the absorption of blood. This evidence of hemorrhage has not heretofore been mentioned or demonstrated in the available reported cases or discussions of peritendinous fibrosis of the dorsum of the hand (also known as dorsal oedema of Secrétan and traumatic hard oedema of the dorsum of the hand); neither has the fibroblastic infiltration of the peripheral portion of the tendon been demonstrated microscopically in this condition, as far as we can determine. In the two

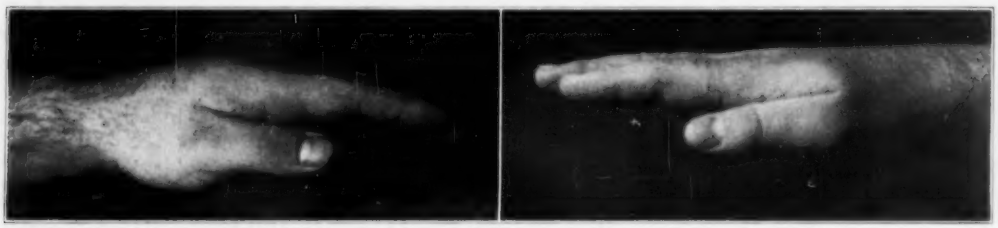

FIG. 2-A FIG. 2-B

Case 2. Left (Fig. 2-A) and right (Fig. 2-B) hands, showing the moderate swelling of the dorsum of the left hand in the region of the distal portion of the third metacarpal.

FIG. 2-C

Roentgenograms of the left and right hands, taken slightly less than two months after the original injury to the left hand. Note the absence of bone atrophy or spotty decalcification.

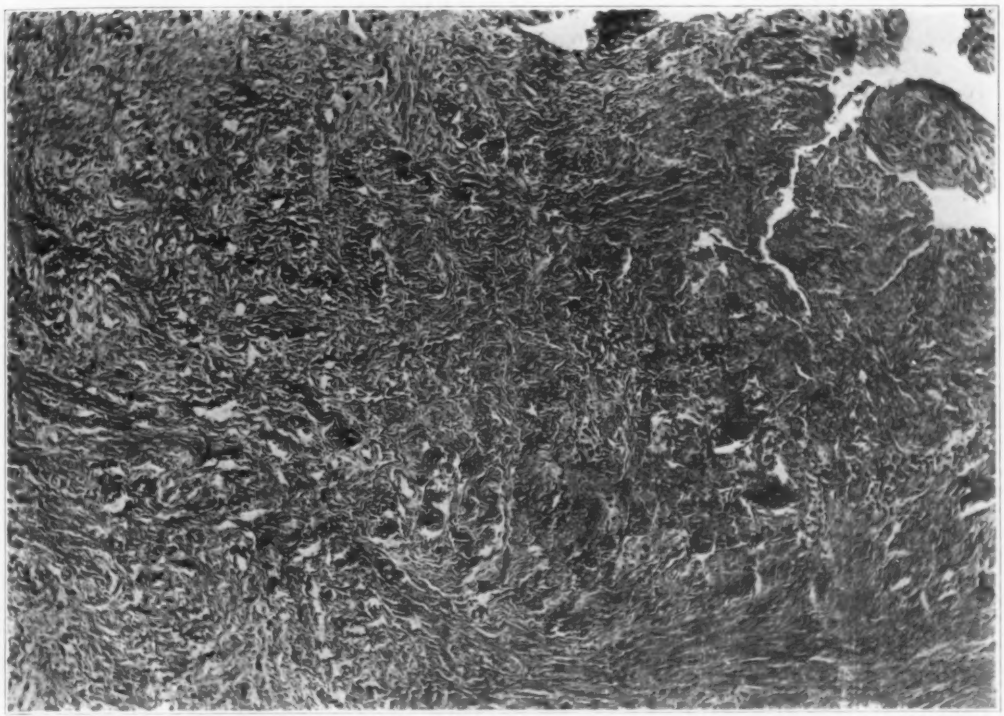

FIG. 2-D

Microscopic section (×92), showing the variation from young fibrous tissue (in the upper left corner) to more mature collagenous tissue (in the lower right corner). Stained with hematoxylin and eosin.

FIG. 2-E

The dark-staining intracellular and extracellular iron pigment is less prominent than in Case 1, because of the shorter duration of the disease. Prussian-blue stain was used (×184).

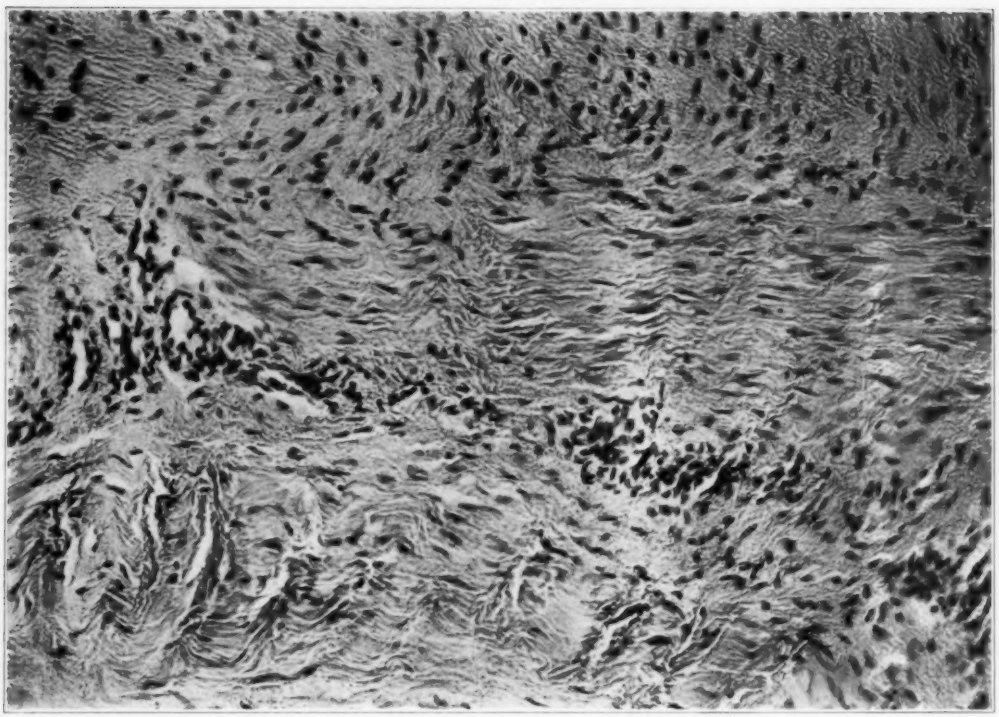

FIG. 2-F

The dorsal peripheral portion of the extensor digitorum communis tendon of the middle finger is seen in the lower left corner; note the infiltration of fibroblasts into and about the peripheral segment of the tendon. Stained with hematoxylin and eosin (×184).

present cases, the initial hemorrhage could reasonably be assumed to be on the basis of severe trauma. As elsewhere, the clotted hematoma (as found in Case 1) is absorbed by the invasion of fibroblasts, which in this condition also infiltrate the adjacent tendon over a considerable length, as shown at operation. (It should be noted that the extensor tendons over the metacarpal area are not protected from an adjacent hematoma by the presence of synovial sheaths, as at the dorsum of the wrist or to a considerable extent on the palmar aspect of the hand and fingers.)

The demonstration of iron pigment within the tendon in Case 2 suggests that a certain fragmentation of the tendon occurs at the time of injury, permitting intratendinous infiltration of blood and possibly predisposing to fibroblastic invasion and fixation of the fragmented tendon. With motion of the tendon, bleeding may easily occur from disruption of the attached young fibrous and granulation tissue, and less easily from tearing of the collagenous tissue, resulting in the recurrence of the hematoma and clinical swelling. Depending upon the degree of absorption of the hematoma, its size can be quite variable; a small hematoma is easily missed in the mass of fibrous tissue. The clotted blood cannot be aspirated and, with the secondary fibrosis, gives rise to a firm, hard swelling, localized to the dorsum of the hand. This latter finding has not been satisfactorily explained heretofore by any neurovascular theory of causation. It should be noted, however, that this focus of hemorrhage, fibrosis, and scarring might well act as a source of an afferent impulse for a reflex arc involving the sympathetic fibers, to produce a secondary oedema on a neurovascular basis. The absence of reported permanent cures following cervical sympathetic procedures in long-established cases is noteworthy; such procedures affect only the secondary phenomena rather than the primary disorder, as demonstrated here.

Anson and his associates have recently completed a detailed study of the several layers of fascia on the dorsum of the hand. It is probable that the absence of superficial

ecchymosis in recurrent peritendinous fibrosis is due to the occurrence of hemorrhage, deep to the superficial layers of fascia; this was true in both of the cases reported. As demonstrated (Fig. 2-F), the area of fibrosis is in the immediate vicinity of the tendons, probably deep to the supratendinous fascia (which Anson has compared to the palmar aponeurosis on the volar aspect of the hand). The superficial lymphatics of the fingers and borders of the palm drain to the dorsum of the hand; their obstruction by pressure of a large hematoma and severe secondary fibrosis, as seen in Case 1, gives rise to the milder oedema of the fingers, as well as that at the border of the palm. Since the osmotic pressure of a relatively large hematoma is unknown, its exact effect on the principal lymphatic channels is a speculative one; a high osmotic pressure would result in an increase in the volume of the hematoma, producing further obstruction of the lymphatics. It is obvious that the pressure of the hematoma and surrounding fibrosis would tend to produce venous stasis by pressure on the dorsal venous arch and its tributaries. In the advanced and more severe case (Case 1) marked wrinkling of the skin, associated with complete disappearance of the finger swelling, followed operative evacuation of the hematoma. The presence of the dorsal fibrosis and hematoma does not obstruct the lymphatic drainage of the central portion of the palm, which drains into the deep lymphatics along the palmar arch; the absence of the palmar swelling is thus readily explained on an anatomical basis.

GENERAL CONSIDERATIONS

Etiology

Males are more frequently affected, particularly laborers, miners, and brewery workers. The incidence of the condition in the United States is probably higher than the paucity of recorded cases would indicate. The possibility of chronic infection has not been generally confirmed by biopsy findings; cases of infectious tenosynovitis constitute a different entity.

Theories like that of Leriche have been advanced to explain the condition on a neurovascular basis [2, 4, 7, 8, 11]; a disturbed sympathetic-nerve control of the lymphatic vessels has been postulated by Schörcher. The skin on the dorsum of the hand is not so firmly fixed by its underlying tissues as that on the palm, which predisposes to subcutaneous swelling; yet it is difficult to understand how a disturbance of the sympathetic nervous system could produce a hard oedema on the back of the hand and fail to affect the bones or soft tissues of the palm. It should be noted that Leriche has produced marked reduction in the size of the swollen hand by a cervical sympathetic procedure. Watson-Jones has suggested that a disturbance in oxalate metabolism may be a factor. In the typical case, the onset of symptoms is precipitated by a blow on the dorsum of the hand, and less commonly by a fracture of a metacarpal bone. As noted by Iselin, an artificial element may be present in certain cases; he points out that self-traumatization of the dorsum of the hand may produce the condition. Coley, in a personal communication, has stated that he is aware of such cases. The predisposing effect of blood dyscrasias or hemorrhagic disease to this affection has apparently received little or no mention in the literature. The relationship of hard post-traumatic swelling to the hand oedema after infections, mentioned by Kanavel, has not been well defined; the deposition of fibrin is apparently less evident in the present cases. The confusion between the two is illustrated by the fact that a case of oedema, following an open suppurating wound with fever and, later, Sudeck's atrophy, has been classified erroneously as traumatic hard oedema [10]. Evidences of psychoneurosis and constitutional inferiority have been reported in certain cases by Bettmann and Leffmann.

Pathological Findings

Microscopic studies have not frequently been made. The pathology has not been clearly understood. On exploration, the peritendinous tissues are found to be hyperaemic and thickened [15]. In one biopsy, described in the early stage of the disease by Schörcher, the tissue was devoid of inflammation. In the later stages of the disease, perivascular in-

flammatory changes are said to occur, and the connective tissue is increased in amount and coarse in character.

Symptomatology

Swelling on the dorsum of the hand occurs shortly after the local injury, and may involve only a portion of the dorsal area. In the severe cases, the skin on the back of the hand has a smooth, stretched appearance. The normal bony prominences become obliterated, and the subcutaneous ridges of the extensor tendons are no longer visible. The hand may feel cool or warm to the touch; no abnormalities of the radial and ulnar pulsations have been reported.

The character of the swelling is firm and hard. In severe cases a milder swelling appears at the borders of the hand and in the fingers, particularly on their proximal dorsal surfaces. The swelling on the dorsum of the hand persists for several weeks or months. With the swelling, an inability to completely flex the fingers occurs; in contrast, motions of the thumb are normal. Later in the course of the disease, finger motion is further inhibited by muscle atrophy and secondary contracture of the joint capsules of the fingers. After the initial injury the pain is most often dull in character, but is increased by extreme flexion of the fingers, as well as by local pressure on the dorsum of the hand. As the swelling subsides, the pain tends to disappear. No sensory or motor changes were reported by Secrétan; the organic basis of diminished sensation, more recently reported by Bettmann, has not been established.

Diagnosis

Usually a fractured metacarpal is suspected when the patient is first seen. The typical history (of acute trauma), the symptomatology, and the roentgenographic findings readily differentiate the condition from the usual traumatic and infectious disabilities of the hand. Sudeck's atrophy and trophic oedema are associated with typical bone changes. Hysterical and functional oedema, due to a prolonged dependent position of the affected limb, is more generalized and is soft in character; personality changes may be readily evident. Less common conditions to be differentiated include causalgia, arthritis, lymphoedema, thrombophlebitis, tuberculosis, and retained foreign bodies.

Prognosis

It has become generally recognized that recurrence of swelling is common, and the number of permanently cured cases is reported by Bettmann as small. Iselin states that the "oedema" persists indefinitely; the incapacity is often 60 to 75 per cent.; and the prognosis is very bad. Watson-Jones has noted a tendency to recurrence even after the swelling has disappeared for a time; he considers the prognosis not good.

Treatment

Numerous methods of treatment have been used. Such therapeutic measures include heat, massage, warm baths and compresses, incision and excision of the involved tissue, cataphoretic histamine and acetylcholine, suggestion, psychotherapy, deep roentgenotherapy, thread drainage, immobilization in plaster-of-Paris casts and splints, compression bandage, low-oxalate diet, various sympathetic blocks, and sympathectomies. A practical form of treatment is suggested by Watson-Jones, who recommends prolonged immobilization in a dorsal plaster splint; this should be continued for several months after the swelling has subsided.

SUMMARY AND CONCLUSIONS

Two cases are presented of soldiers who suffered from recurrent, disabling, hard swelling on the dorsum of the hand, following a severe initial blow. In each case operative

exploration and examination of pathological specimens revealed evidence of old and recent hemorrhage, with fibrous-tissue proliferation and organization in the hemorrhagic area. Infiltration of the extensor tendon by the fibrous tissue gives explanation for the clinical finding of local pain and limitation of movement during flexion of the fingers; also, it is evident that, with extremes of motion of the tendon, disruption of the attached fibrous tissue occurs with further hemorrhage, clotting, fibroblastic organization, and increased fibrosis deep to the superficial fascia. This explains the recurrent, localized, and hard character of the swelling.

In such cases it would appear that the treatment of choice is early operative evacuation of the primary hematoma and ligation of any evident bleeding vessels, followed by a firm compression dressing. Involvement of the extensor tendons during the fibroblastic organization of the adjacent hematoma cannot otherwise be avoided with certainty. In late cases, evacuation of the hematoma should probably be followed by prolonged immobilization, in order to allow maturation of the fibrous tissue and obliteration of the hematoma cavity. The authors are not prepared as yet to state the value in advanced cases of excision of the involved tendons, subcutaneous tissue, and skin, with replacement by a pedicle skin graft and tendon transplants. Such procedures are certainly contra-indicated in cases with a factitial etiology, in old cases with severe joint contracture and marked loss of function, and in those with marked secondary sympathetic-nerve phenomena.

Probably not all cases of peritendinous fibrosis of the dorsum of the hand have a similar basis. In our opinion this present hemorrhagic type constitutes a definite subdivision of a group of ill-defined cases which follow a definite syndrome and are resistant to the usual treatment. The presence or absence of this hemorrhagic type should always be established before other operative procedures, such as various types of cervical sympathectomies, are performed. Permanent good results cannot logically be anticipated with cervical sympathetic procedures in those cases in which fibroblastic infiltration and fixation of the extensor tendons have occurred.

NOTE: Appreciation is expressed for the special examinations, help, and cooperation of all officers concerned with these case studies, particularly Lieutenant Colonel Isadore Pilot, M. C., Captain Robert Hartman, M. C., and Captain David Johnson, Sn. C.

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EXPERIENCES IN THE TREATMENT OF INTRACAPSULAR FRACTURES OF THE NECK OF THE FEMUR*

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From the Instituto Traumatologico, Montevideo

The purpose of this paper is to set forth an analysis of the results obtained in our Clinic over a ten-year period in the treatment of intracapsular fractures of the neck of the femur. For this purpose, we have reviewed 325 cases, with an average follow-up of two years or more; this analysis has led to a series of conclusions, which have pointed the way to our present form of treatment. Similar procedures have been carried out successfully by American orthopaedic surgeons, and our conclusions may be the same as those of our colleagues in the United States.

It is commonly known that the general condition of the patient must be considered before any direct attack can be made upon the fracture of the femoral neck. In many cases, the general condition will contra-indicate any active treatment of the fracture; according to our statistics, 123 cases or 38 per cent. were of this type. Twenty-nine of these patients died between the first and third weeks. Other conditions which precluded fracture treatment were heart failure, cerebral softening, uraemia, senility, et cetera, and there

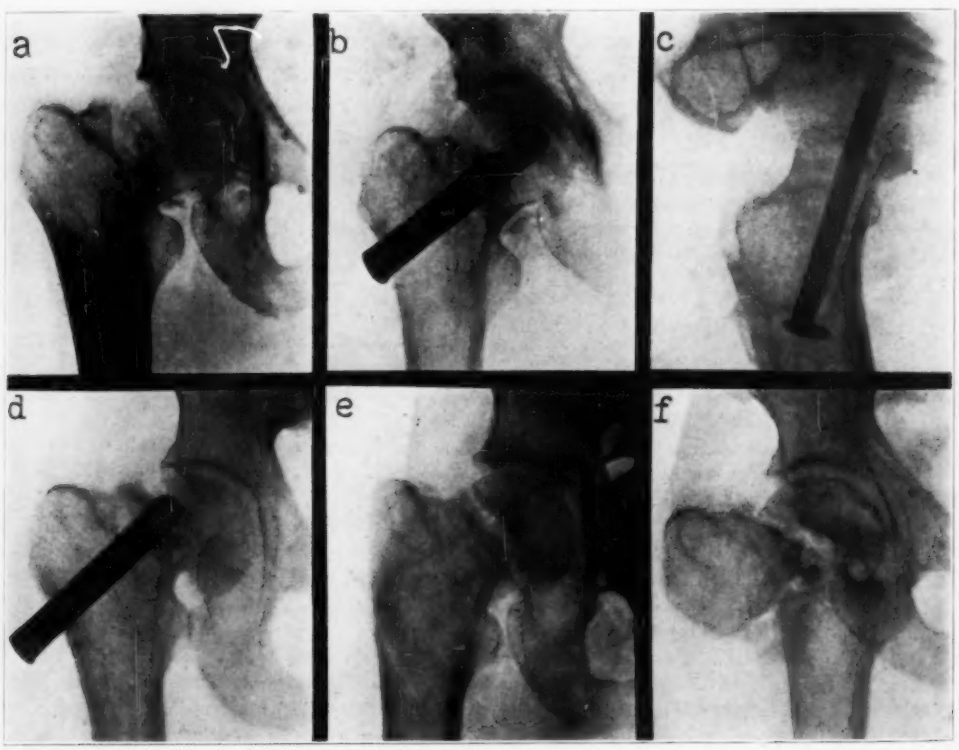

FIG. 1

Case 3321. Modification of Smith-Petersen nail in patient, sixty-eight years old.
a: Preoperative roentgenogram. *b* and *c:* Immediately after operation.
d: Thirteen months after operation, the nail had undergone spontaneous migration and the fracture was reproduced.
e: After removal of the nail. *f:* Five months after osteotomy, the result was very good.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1947.

FIG. 2

Case 1301. Modification of Smith-Petersen nail in a patient, forty-eight years old.
a: Preoperative roentgenogram. *b* and *c:* Immediately after operation.
d: Eight months later, the result is good.

FIG. 3

Case 8215. Godoy-Moreira Vitallium screw was used in patient of sixty-four years.
a and *b:* Immediately after operation.
c and *d:* Three years after operation the result was good.

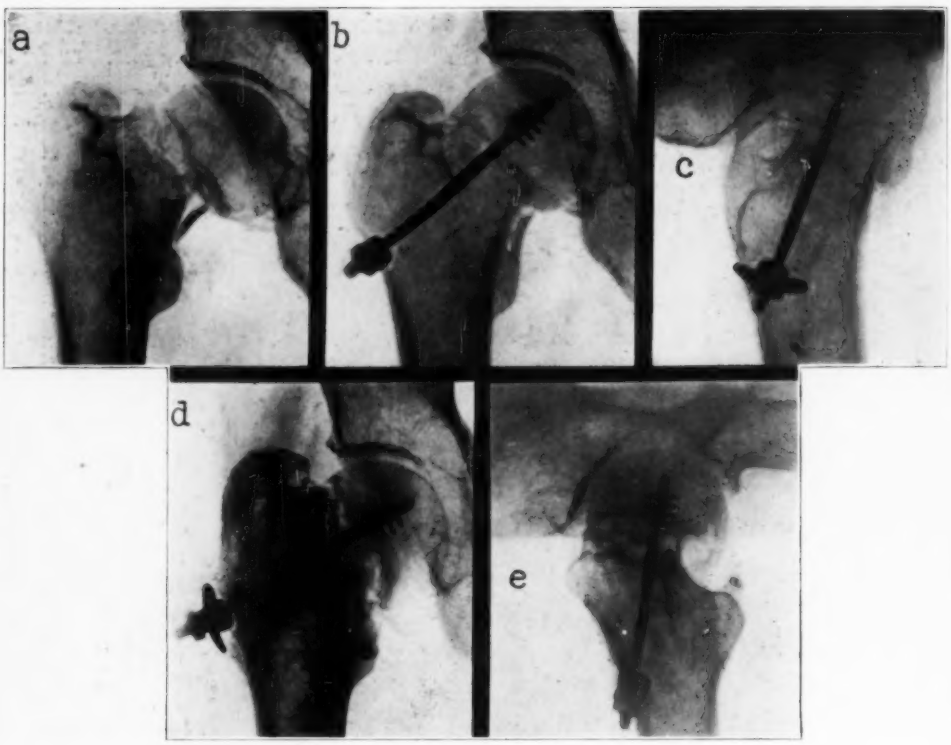

FIG. 4

Case 13876. A Godoy-Moreira screw was used in this patient of seventy years.
a: Before operation. *b* and *c:* Immediately after operation.
d and *e:* Twelve months after operation, callus had not yet formed. The result in this case was bad, with absorption of the neck and external rotation.

were also cases of tabes, syphilitic changes in the hip, tuberculosis, and metastatic disease in the neck of the femur. A rule was finally evolved that no person over fifty years of age with a fracture of the neck of the femur should be operated upon until he had received at least one week of medical observation and treatment. This rule may have helped to attain low mortality rates in our subsequent treatment of the fracture. There were no operative deaths following nailing with the three-flanged nail; of the patients who had had screws applied to the fracture, 2.2 per cent. died as a result of the operation and 7.9 per cent. died as a result of osteotomy.

Of the total of 325 cases reviewed, only 202 actually received treatment of the fracture. In forty of these cases, impaction was present, and the patients were treated in plaster casts with early ambulation. All of this group showed good healing, with excellent function. Four patients were treated with the Whitman plaster, and two of them showed good results. Of the remaining patients, twenty-five were treated by fixation with a three-flanged nail, forty-five had fixation with the Godoy-Moreira screw, seventy-six had primary osteotomy, and twelve had primary bone-grafting.

In the group treated with the three-flanged nail, the ages ranged from twenty-one to eighty-one; 52 per cent. showed bony union roentgenographically, and good function. Complications occurred, however, in this group with good results. One nail was extruded; in one case the head showed aseptic necrosis; in one case there was coxa vara; and in three cases there was absorption about the nail, as well as local tissue reaction to the metal. In 48 per cent. the results were judged as not good: Six patients showed fully developed aseptic necrosis, three had coxa vara, two had non-union, and in one the position was lost after thirteen months. Four of these patients needed subsequent osteotomies.

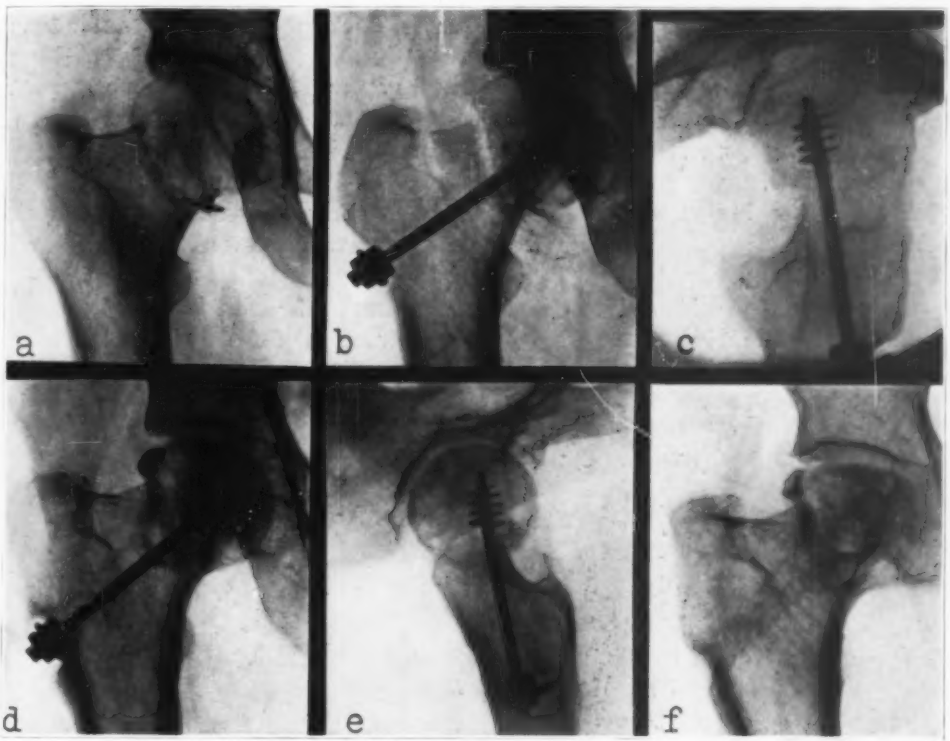

FIG. 5

Case 11338. A Godoy-Moreira screw was used in this patient, aged fifty-seven years.
a: Before operation. *b* and *c:* Immediately after operation.
d and *e:* Twelve months after operation, there was necrosis of the epiphysis.
f: Twenty months after operation. The screw has been removed.

In the forty-five cases in which the fracture was fixed with the Godoy-Moreira screw, twenty-four or 53.3 per cent. showed good clinical and roentgenographic results; in 20 or 44.4 per cent. the results were not good; and there was one death or an operative mortality of 2.2. per cent. Here again, aseptic necrosis occurred in ten cases, absorption of the neck

FIG. 6

Case 9571. Thirty months after osteotomy; the results were excellent.

in thirteen cases, and the screws broke in two cases. The screws were removed in ten cases, and five patients had subsequent osteotomies.

In seventy-six cases, intertrochanteric osteotomy was the primary treatment. There were six deaths in this group, or an operative mortality of 7.9 per cent.; follow-up in nine of the cases was not possible. Of the remainder, the results in 54 or 88 per cent. of these cases were considered to be very good. The patients were able to walk without support and without pain. However, in no case was flexion possible beyond 90 degrees, and the motions in rotation and abduction were slightly more than a jog. The results were considered unsatisfactory in 7 or 11.7 per cent. of the cases.

Intertrochanteric osteotomy had been our treatment of choice, both as a primary and a secondary operation, in the majority of cases of fracture of the neck of the femur until the past year. This was because the result could be predicted more surely, and also because it was a good procedure when other methods had failed. It was because of the large number

FIG. 7-A FIG. 7-B

Case 16970. Anteroposterior and lateral roentgenograms of a patient, sixty-four years old.

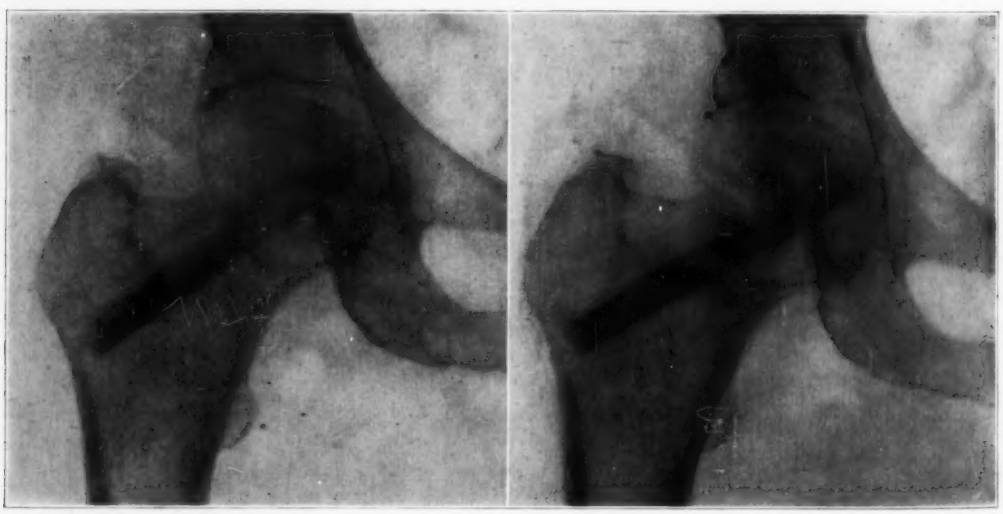

FIG. 7-C FIG. 7-D

Fig. 7-C: Two weeks after operation.
Fig. 7-D: Two months after operation. Patient is still in the plaster cast.

FIG. 7-E FIG. 7-F

Anteroposterior and lateral roentgenograms three months after operation. The plaster has been removed.

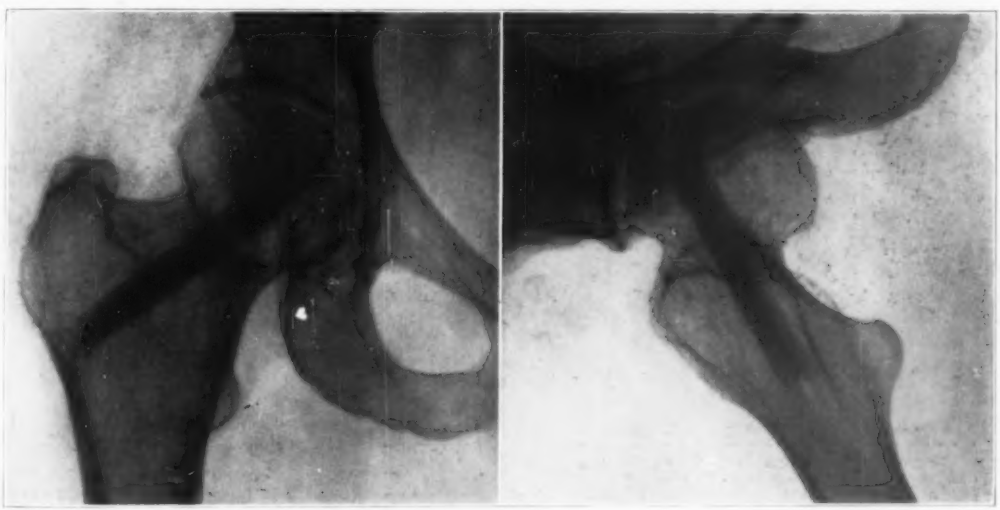

FIG. 7-G FIG. 7-H

Anteroposterior and lateral views, fifteen months after operation.

of failures in cases treated either by the nail or the screw that we began to favor the intertrochanteric osteotomy. Even more important was the fact that no possibility existed of foreseeing or predicting the result with metal fixation, and it made us feel that this form of treatment was uncertain. However, in spite of the fact that results were satisfactory with intertrochanteric osteotomy, we sought a better method in the hope that we could get union and at the same time preserve better function. Since we had previously noted the absence of aseptic necrosis in the cases of slipped epiphyses treated by reduction and bone-grafting, a similar procedure was considered for recent traumatic fractures of the neck of the femur.

To date, twenty-five such cases have had primary bone-grafting after closed reduction. Twelve of these have been analyzed, and all of them show uniformly good results. The point which is most interesting is that, if the roentgenogram shows satisfactory findings in this group at four months, they will be better at six months, and still better in ten months.

Also, there was a notable absence of the surprises which were so usual in the subsequent roentgenograms of cases treated with metal fixation.

TECHNIQUE OF OPERATION

Under spinal anaesthesia, the patient is placed carefully on an orthopaedic operating table, and closed manipulation is carried out as often as is necessary until good reduction has been demonstrated in both anteroposterior and lateral roentgenograms. The operative field is then prepared, and a short incision is made over the upper end and the shaft of the femur. The tubercle of the vastus lateralis is identified, and a wire is started up the neck from a distance two centimeters below this point. The wire is of a known length and, when eight centimeters have gone in, its position is checked by roentgenogram. This is repeated, if necessary, until a favorable position of the wire has been obtained. A perforation along the neck is then made with a hollow drill, which follows the wire as a guide. When this has

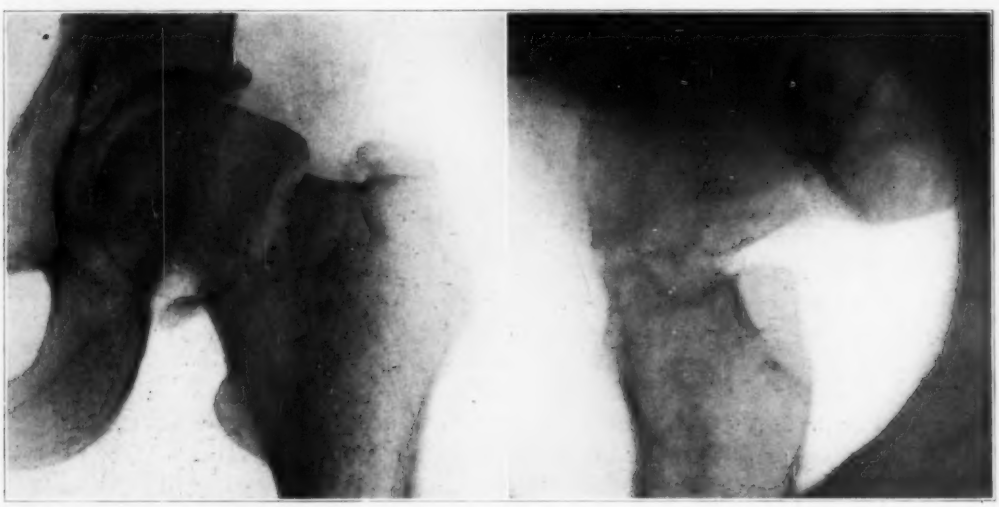

FIG. 8-A FIG. 8-B

Fig. 8-A: Case 18225. Anteroposterior view, taken before operation, in patient fifty-two years old.
Fig. 8-B: Lateral roentgenogram, taken before operation.

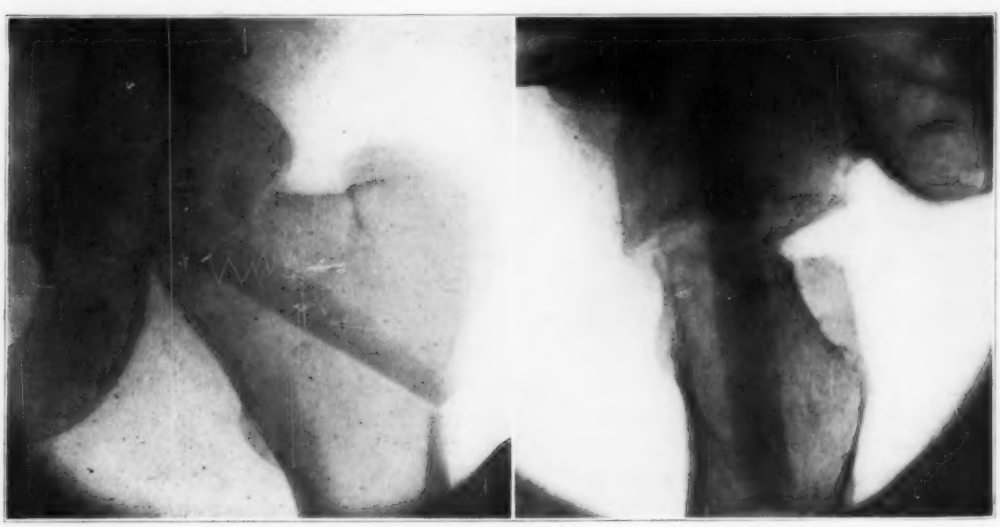

FIG. 8-C
Immediately after bone-grafting operation.

FIG. 8-D
Lateral view.

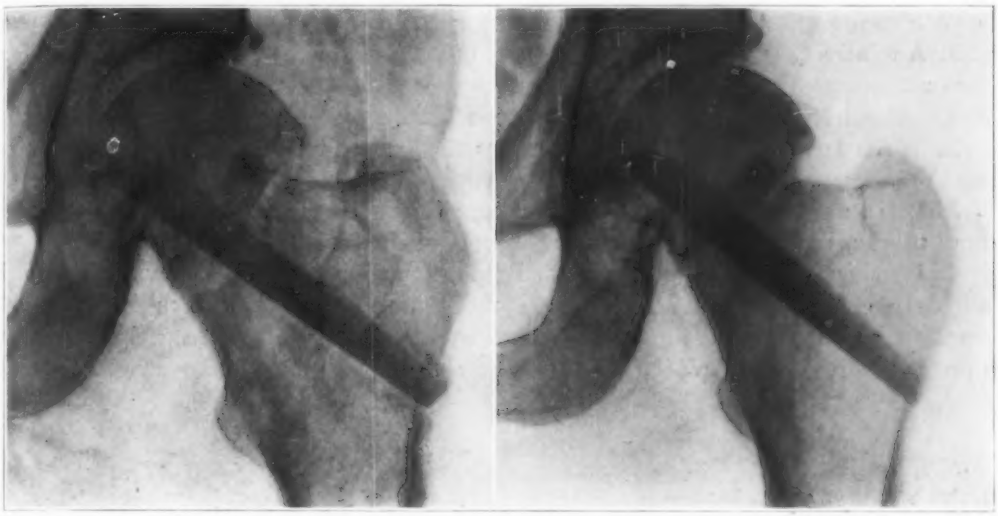

FIG. 8-E FIG. 8-F

Fig. 8-E: Roentgenogram taken one month after operation, while patient was in a plaster cast.
Fig. 8-F: After removal of the plaster, three months after operation.

FIG. 8-G FIG. 8-H

Fig. 8-G: Lateral view, eight months after operation.
Fig. 8-H: Hip mobility is normal, eight months after operation.

gone in the appropriate distance, it is removed and a drill of larger size is introduced. In order to hold the position of reduction, we have frequently fixed the head to the neck by two wires, one at the superior portion and one at the inferior portion of the head. In using reamers or progressively larger drills, care must be taken to avoid making a false path, and this is accomplished mostly by the "feel" of the instrument.

A bone graft, triangular in shape and including the tibial crest, is taken from the tibia. The desired length and width of this graft should be determined by the channel made in the neck of the femur. The graft is then driven carefully into the created tunnel, care being exercised that it is the proper size and that it goes in the proper direction. Roentgenograms are again taken to be certain of the correct position of the graft, and the films must be interpreted very carefully. Usually at least eight roentgenograms are necessary, and often more. The wound is then closed and the patient is placed in a single hip spica for three months.

CONCLUSIONS

1. A relatively large number of fractures of the neck of the femur occur in which no active attention can be given to the fracture, because of the general condition of the patient. About 65 to 70 per cent. of the cases receive active treatment for the fracture.

2. Various methods of treatment with metallic fixation leave a great deal to be desired as to the outcome.

3. Osteotomy as a primary therapeutic procedure allows more certainty in the prediction of results, but demands the sacrifice of part of the function of the hip.

4. Primary bone-grafting after closed reduction eliminates the disadvantages of the methods described here; that is to say, it will more surely prevent aseptic necrosis and neck resorption, and at the same time it will maintain better hip function. At the present time, we prefer this method of treatment to all others, because the results have been better.

PSEUDARTHROSIS IN THE LUMBOSACRAL SPINE *

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Some in this audience will remember the furor with which surgical fusion of the spine was greeted when it was first proposed. Despite the fact that various complications soon became apparent, this procedure, at first proposed for tuberculosis of the spine, was gradually extended to include the treatment of many conditions. Among these were numerous disabling lesions involving the lumbosacral area. The obvious dangers of mortality and complications after such operations have been fairly well established, and accounts of pseudarthroses or failures of continuity in desired fusion areas have been recounted in a few series. Comparative statistics or percentages of pseudarthroses developing as a result of operative procedures employing varying techniques, carried out by the same limited personnel, are, to our knowledge, not available. While the operations reported here were all performed by three surgeons, they were carried out at six different institutions. This would indicate that the results were not due to unusual hospital advantages, but were the result of uniform surgical technique and ability. The mortality and complications have proved to be of minor importance. Failure of accomplishment of the desired end—namely, successful arthrodesis of a selected series of vertebrae in the lumbosacral region—has proved to be of major importance. We shall herewith review and report failures of fusion occurring in a consecutive series of patients in whom arthrodeses were attempted across the lumbosacral joint. The paper will be divided into two main parts: first, the incidence of pseudarthrosis in fusion of the lumbosacral spine; and, second, statistics regarding the repair of pseudarthroses.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1947.

TABLE I

RELATION OF PSEUDARTHROSIS TO EXTENT OF FUSION AND NUMBER OF PATIENTS WITH SOLID FUSION NOT RELIEVED OF PAIN

Fusion Intervals	No. of Operations	Pseudarthroses		Pseudarthroses		Solid Fusion without Relief of Pain	
		No.	Per cent.	With Pain	Without Pain	No.	Per cent.
Fifth lumbar to first sacral	145	5	3.4	3	2	17	11.7
Fourth lumbar to first sacral	357	62	17.4	36	26	15	4.2
Third lumbar to first sacral	78	26	33.3	15	11	1	1.3
Second lumbar to first sacral	18	6	33.3	4	2	0	0

INCIDENCE OF PSEUDARTHROSIS IN FUSIONS OF THE LUMBOSACRAL SPINE

Pseudarthroses in the Total Series

Clinical Incidence: In this series of cases, 647 operative procedures were carried out on 594 patients. The average postoperative follow-up period has been thirty-four months. No result has been accepted as regards solidity of fusion with less than one year of follow-up, unless controlled by both lateral roentgenograms in flexion and extension and by anteroposterior roentgenograms in right and left bends. Among the 594 patients upon whom spine fusion was performed, pseudarthroses developed in 119 instances or 20 per cent. This represents a percentage of basic failure which requires improvement.

True Incidence: Scientifically and factually, it has seemed important to determine the development of pseudarthroses according to the number of intervertebral spaces involved. Among the 594 patients, 1,329 spinal intervals were bridged. Pseudarthrosis occurred at 161 intervals among these patients, or 12.1 per cent. This represents the relative inefficiency of this type of surgery.

Incidence of Pseudarthrosis as Related to Extent of Fusion: We had expected that the percentage of pseudarthrosis would rise rapidly as the number of spinal intervals which were crossed increased. This was found to be true. When the fifth lumbar interval alone was bridged, pseudarthrosis developed in only 3.4 per cent.; when fusion of the fourth and fifth lumbar intervals was attempted, pseudarthrosis developed in 17.4 per cent.; as another interval was added, covering the third, fourth, and fifth lumbar intervals, the proportion rose rapidly to 33.3 per cent., and remained relatively the same as other intervals were added (Table I). A patient was often relieved of preoperative symptoms, in spite of the development of pseudarthrosis. Of all patients in whom pseudarthroses developed, 41.4 per cent. were relieved of the pain and disability which had been present before operation.

This analysis showed that a certain number of patients were unrelieved, even though solid fusion developed. This percentage rapidly decreased from 11.7 to 0 as the number of intervals successfully crossed was increased from one to four. To secure relief of symptoms for the greatest percentage of patients requires, therefore, a delicate balance. As the area of fusion is lengthened, there is an increase in the incidence of pseudarthrosis, but a marked decrease in the number of patients with solid fusion who are unrelieved of their symptoms.

Influence of Bending Roentgenograms on Results: Failure of fusion was demonstrated much more frequently when roentgenograms of front and side bending (biplane) were

superimposed (Fig. 1) than by the use of flat roentgenograms and clinical observation. In these biplane roentgenograms, the lateral flexion and extension plates should show the fused elements completely superimposed. In the superimposed anteroposterior lateral-bending roentgenograms, the fused elements appear as if stereoscoped, but the borders of the bodies of the spinous and transverse processes are parallel[1]. As early as 1933, lateral flexion and extension roentgenograms were occasionally used (Fig. 2). For more accurate determination, we frequently connect comparable points on the vertebrae with lines and superimpose these. Since 1940, roentgenograms with motion in two planes have been superimposed in order to denote solid arthrodesis. The use of such superimposed roentgenograms has increased the *known* percentage of pseudarthrosis, when tabulated both as to clinical incidence and true incidence.

In a review of this series of cases, only 11.8 per cent. were diagnosed as having failure of fusion by clinical judgment and flat roentgenograms. In 21 per cent. of the patients, pseudarthrosis was shown by biplane bending roentgenograms. The authors believe that the increased percentage shown to have pseudarthroses by the bending roentgenograms indicates accurately that clinical judgment, aided by flat roentgenographic plates, does not truly establish the number of pseudarthroses present in any series.

Relation of Pseudarthrosis to Primary Lesion for which Arthrodesis Was Performed

Posterior Herniation of the Intervertebral Disc: Here are grouped only those cases which had frank herniations of the disc with unequivocal extrusion of material. All cases with bulging of the disc, et cetera, are excluded and placed under the heading of lumbosacral strain. Of the typical posterior herniations of the intervertebral disc, pseudarthroses de-

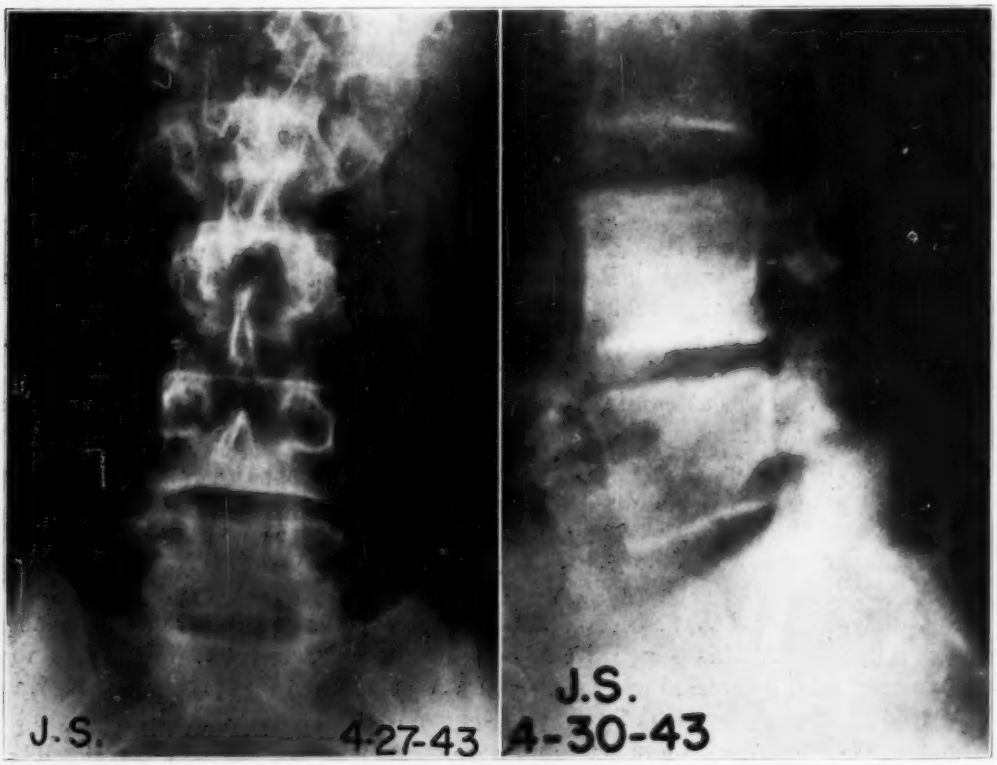

FIG. 1

Biplane bending roentgenograms, superimposed, are essential for determination of the presence of pseudarthrosis. In the lateral view, such roentgenograms should be accurately superimposed in the arthrodesed area. In the anteroposterior view, the elements will appear as if stereoscoped; but the borders of the vertebral bodies, et cetera, will be parallel if fusion is solid.

TABLE II

RELATION OF PSEUDARTHROSIS TO PRIMARY LESION FOR WHICH FUSION WAS PERFORMED

Diagnosis	No. of Operations	Pseudarthroses	
		No.	Per cent.
Posterior herniation of intervertebral disc	158	18	11.4
Lumbosacral strain	289	65	22.5
Tuberculosis	31	5	16.1
Spondylolisthesis	69	16	23.2
Arthritis	37	11	29.7
All others	16	4	25.0

veloped in 11.4 per cent. (Table II). This low percentage is believed to be due to the universal use of the clothespin graft, plus quantities of additional bone.

Lumbosacral Strain: In this group were placed all patients with chronic lumbosacral backache, non-specific sciatic symptoms, and lesions, the basic pathology of which was not clearly disclosed before or after operation. Failure of fusion developed in 22.5 per cent. Before 1940, when biplane bending roentgenograms were not required, there was an incidence of pseudarthrosis of only 15 per cent. Following 1940, with all cases controlled by such roentgenograms, the percentage of pseudarthroses rose to 21.3. Here, again, is clear indication that pseudarthroses are missed with flat roentgenograms and clinical examination alone.

Tuberculosis: Under this heading were included only known tuberculous lesions of the spine. Any questionable lesions of this nature were placed under the heading of arthritis. Pseudarthroses developed in 16.1 per cent. of cases.

Spondylolisthesis: Spine fusion was carried out on sixty-nine occasions, with development of pseudarthrosis in 23.2 per cent. Before 1940, the incidence of pseudarthrosis was

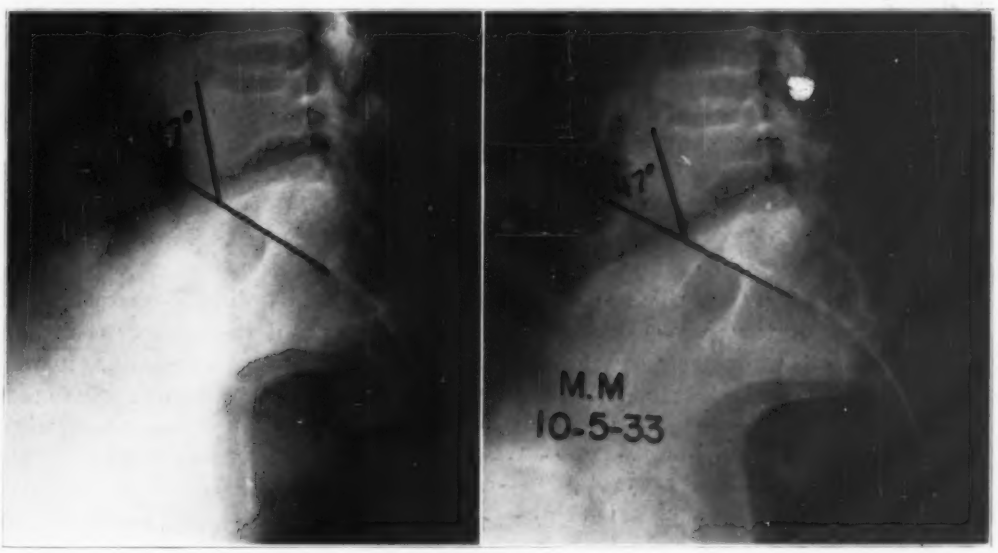

FIG. 2

Lateral views of flexion and extension roentgenograms alone are not sufficient. These were used as early as 1933, but pseudarthroses have been shown to exist by the anteroposterior lateral-bending views, when the lateral views in flexion and extension superimpose with complete accuracy.

TABLE III

DEVELOPMENT OF PSEUDARTHROSIS AFTER VARIOUS TYPES OF OPERATIVE PROCEDURE

Technique	No. of Operations	Pseudarthroses	
		No.	Per cent.
Trisacral fusion	85	9	10.6
Double clothespin graft	356	68	19.1
Iliac strips	74	16	21.6
Local bone	40	12	30.0
Hemifusion	45	14	31.1

TABLE IV

REPAIR OF PSEUDARTHROSIS

Number of pseudarthrosis repairs		43
Repaired once	29	
Repaired twice	4	
Repaired three times	2	
Total number of patients	35	

35 per cent. After 1940, when double clothespin grafts of iliac bone supplemented by iliac strips were first used, the incidence of pseudarthrosis dropped to 16.3 per cent.

Arthritis: Of thirty-seven patients treated by fusion operation, pseudarthrosis developed in 29.7 per cent.

All Others: There were sixteen cases with such diagnoses as foreign body, fracture of the lamina, hemivertebra, or scoliosis. Pseudarthroses were found in 25 per cent.

Pseudarthroses Developing from Various Types of Operative Procedure

Trisacral Fusion: The lumbosacral joints were crossed in this operative procedure in eighty-five instances, with the development of pseudarthrosis in 10.6 per cent. (Table III). In the majority of cases this operative procedure was performed where the fifth lumbar vertebra alone was added to the sacrum, covering only one interval. For this reason a high percentage of successful arthrodeses resulted. Further analysis of the series shows that most of the pseudarthroses occurred where both the fourth and fifth lumbar interspaces were crossed. Where the fifth lumbar vertebra alone was arthrodesed to the sacrum, only 3.3 per cent. of pseudarthroses occurred. When both the fourth and fifth lumbar vertebrae were fused to the sacrum, 29.2 per cent. of pseudarthroses appeared, almost ten times as many as when a single interval was crossed.

Double Clothespin Graft: The double clothespin graft was used in 356 operations; 19.1 per cent. of pseudarthroses resulted. Analysis again shows that the number of intervals crossed determines the percentage of pseudarthrosis encountered. In operations in which the fifth lumbar vertebra was fused to the sacrum, one case of pseudarthrosis was found or 2.1 per cent. When two spinal intervals were crossed, 16.2 per cent. of pseudarthrosis occurred. When three intervals were crossed, the pseudarthrosis rate rose to 39.2 per cent.

Iliac Strips: In seventy-four operations, strips of iliac bone were used without other support; pseudarthroses developed in 21.6 per cent. This is nearly as good a record as with the double clothespin graft. Immediate stability following operation, however, is lacking.

Local Bone: When bone from the posterior elements of the vertebrae themselves was used, without reinforcement of osseous material from adjacent structures, the percentage of pseudarthrosis rose to 30.

TABLE V

LOCATION OF PSEUDARTHROSIS AND INTERVALS INVOLVED

Multiple Locations		Intervals Involved	
No. of Interspaces	No. of Cases	Location	No. of Times
1	19	Second lumbar	3
2	12	Third lumbar	6
3	4	Fourth lumbar	31
4	2	Fifth lumbar	23
Total number of pseudarthrosis intervals			63

Hemifusion: In forty-five operations, iliac strips of bone were placed entirely on one side of the spinous processes, in contact with the underlying laminae. Of these, pseudarthrosis developed in 31.1 per cent. The authors had expected to find this method of fusion more satisfactory in this area of the spine.

Arthrodesis of Only the Fourth to Fifth Lumbar Interspace

Arthrodesis of the single interval at the fourth lumbar vertebra was performed on six occasions for disc hernia. In three, the fusion had to be extended to the sacrum, and two other patients are still partially disabled with lumbosacral complaints.

Mortality

Although this summary is concerned mainly with the development of pseudarthrosis, the mortality is reported for the entire series. There were six deaths. Two resulted from shock, two from infection, one from nephritis with resulting anuria, and one from embolus. This represents a mortality rate of approximately 1 per cent. Transfusions have been administered routinely since 1942, starting with operation, and since that date shock has not been a problem.

STATISTICS REGARDING THE REPAIR OF PSEUDARTHROSIS

Of the 119 patients in whom pseudarthrosis developed, only thirty-five returned to the authors for repair. Many of the remainder had symptoms insufficient to demand surgical treatment. A few refused further care or went elsewhere for repair. Forty-three repairs were done on these thirty-five patients (Table IV). In four instances, two repairs were carried out on each patient; and in two instances, three repairs were done. Of the twenty-nine others, each had one attempt at repair. The average time interval from the original spine fusion to repair of the pseudarthrosis was 24.2 months. The average length of follow-up has been 44.9 months. The average age of the patients was 35.6 years. No case was accepted for study until at least a year after operation or unless the result had been checked by biplane bending roentgenograms which were superimposed. Since in no instance in the whole series have we seen a spine fusion become solid later than eight months after operation, when checked by biplane bending roentgenograms, we have accepted results as regards pseudarthrosis as final after such a period, when so controlled. One death occurred in this series of patients operated upon for repair of pseudarthrosis. This death is the one previously reported as resulting from anuria due to nephritis.

Preoperative flexion roentgenograms in two planes have been required in all cases since 1940. Of thirty-one patients, on only one occasion did biplane bending roentgenograms fail to show that a pseudarthrosis was present. In twelve cases in which flat roent-

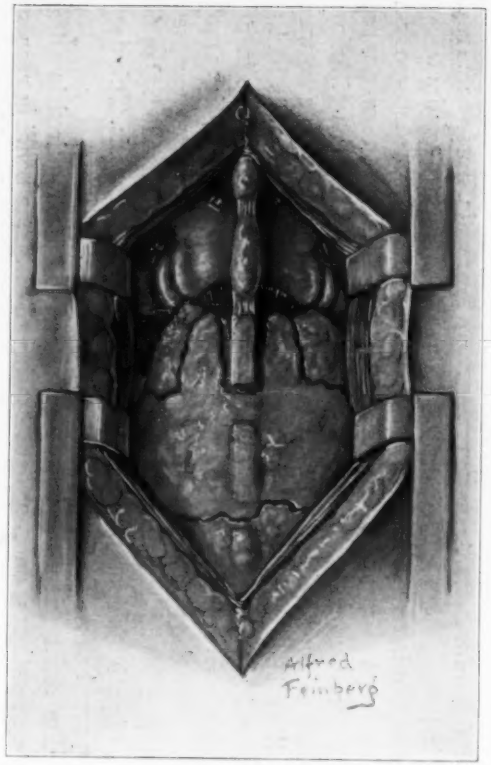

FIG. 3-A

FIG. 3-B

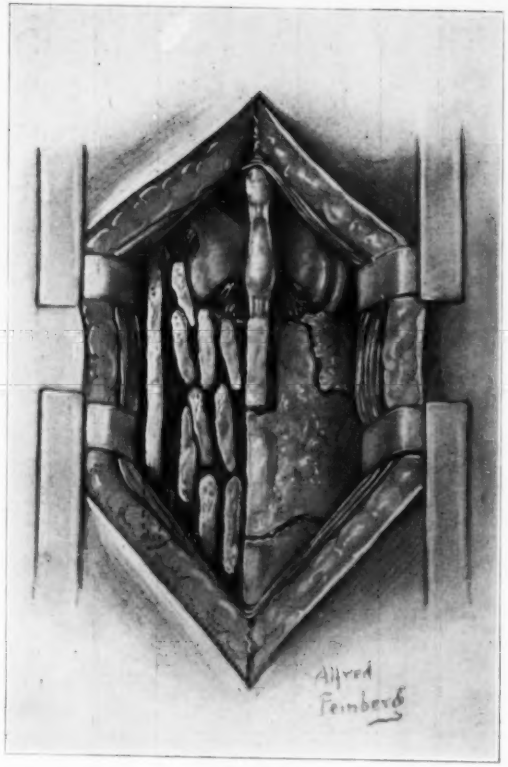

FIG. 3-C

Fig. 3-A: Two types of pseudarthrosis are shown,—the usual transverse type and the type occurring at the end of a clothespin graft.

Fig. 3-B: Repair of such pseudarthroses is carried out on one side only. Transverse processes and articular facets are exposed, and the site of previous fusion is denuded on its posterior surface only.

Fig. 3-C: A wide iliac strip is set vertically on the transverse processes outside the articular facets and in contact with them. Strip grafts of ilium are then placed over the dorsum of the previous fusion on one side, in the angle between the fusion and the vertically placed graft. The remainder of the previous fusion on the opposite side is not even exposed, being shown in the illustration only for clarity. It is left alone for such support as the bony masses already provide.

TABLE VI

FAILURE OF PSEUDARTHROSIS REPAIR ACCORDING TO ORIGINAL DIAGNOSIS

Diagnosis	No. of Operations	No. of Persisting Pseudarthroses	Failures (*Per cent.*)
Posterior herniation of intervertebral disc	9	4	44.4
Lumbosacral strain	20	6	30.0
Tuberculosis	8	2	25.0
Spondylolisthesis	4	1	25.0
Arthritis	2	0	0

genograms alone were taken, four or 33.3 per cent. failed to show pseudarthroses which were found later at operation. Furthermore, we have on many occasions seen apparently solid fusion in lateral flexion and extension roentgenograms, whereas anteroposterior lateral-bending roentgenograms showed pseudarthrosis to exist. It is the authors' firm conviction that all cases of fusion in the lumbosacral spine must be checked with *biplane* bending roentgenograms for satisfactory statistics to be secured.

Location of Pseudarthrosis

The forty-three operations for repair of pseudarthrosis covered sixty-three spinal intervals with failure of fusion; in other words, more than one pseudarthrosis was found at operation in several of the patients. Most of the pseudarthroses were located at the fourth lumbar interspace; the next most frequent number were at the fifth lumbar interval (Table V). The great number found at these two intervals is accounted for by the fact that most of the spine fusions crossed them. Although all operations crossed the fifth lumbar interspace, the greatest number of pseudarthroses were at the fourth lumbar. This may be because of the relative instability of the fourth lumbar as compared with the fifth lumbar. In the twenty-five instances in which a single pseudarthrosis was found, six or 24 per cent. failed of repair. Of the twelve patients with two pseudarthroses each, only 50 per cent. success was obtained at repair. In the remaining six patients with more than two pseudarthroses, the percentage of success was even lower. Repair of pseudarthrosis is appreciably more difficult than original fusion.

Success of Pseudarthrosis Repair as Based upon Original Diagnosis

Nine repairs of pseudarthrosis were performed in which the original diagnosis was posterior herniation of the intervertebral disc (Table VI). There was failure to secure ankylosis in 44.4 per cent. Where lumbosacral strain had been the original diagnosis, there were twenty cases with 30 per cent. of pseudarthroses developing after attempted repair. Among eight patients with an original diagnosis of tuberculosis, there was 25 per cent. failure of repair. Spondylolisthesis patients showed 25 per cent. failure of refusion. Two arthritic patients who had pseudarthroses repaired both secured solid ankylosis.

TABLE VII

RELATION OF FAILURE OF PSEUDARTHROSIS REPAIR TO TYPE OF OPERATION USED

Technique	No. of Operations	Failures	
		No.	Per cent.
Iliac strips	18	4	22.2
Double clothespin graft	14	4	28.6
New procedure	7	2	28.6
Local bone	4	3	75.0

Relation of Failure of Pseudarthrosis Repair to Type of Operation

In eighteen patients, iliac strips were used on both sides of the mid-line, with four failures or 22.2 per cent. (Table VII). These were the simpler cases. When the clothespin or buttress graft was reapplied, together with iliac strips, there were fourteen cases with four failures, a percentage of 28.6. A new procedure was developed for the more difficult cases (multiple pseudarthroses), in an attempt to reduce the percentage of failure. By this type of procedure, seven cases have been treated with two failures (28.6 per cent.). Since these were the cases with two or more pseudarthrosis intervals each, it can be seen that the reduction from 50 per cent. failure to 28.6 per cent. failure may represent a real advance. This operation will be described herewith. Local bone was used on four occasions with three failures (75 per cent.). These cases were treated many years ago, before it had become routine to add iliac or other bone strips.

In three patients a typical herniation of intervertebral-disc material was removed from beneath a pseudarthrosis.

Postoperative Care

Plaster jackets were used postoperatively for five months or more in twenty instances. Of these, new pseudarthroses developed in seven or 35 per cent. In view of this percentage of new pseudarthroses, we feel that the jacket may be dispensed with and a reinforced lumbosacral corset used.

Causes for Development of Pseudarthrosis

These cases have been explored carefully. Certain outstanding causes of failure of fusion were noted. In all but ten instances, there seemed to be a definite factor which one could recognize for each particular case. In thirteen instances it was clearly evident that an inadequate amount of bone had been used for grafting material. In five instances the pseudarthrosis could be definitely ascribed to the use of solid, heavy tibial bone, not supported by iliac bone or other fine strip grafts. Infection at the original operation for spine fusion, draining sinuses associated with tuberculosis, hematomata resulting from the original fusion, et cetera, occurred in ten instances. In five instances the solid spine fusion (as determined previously by biplane bending roentgenograms) had been fractured. In two of these cases the spinous process at the upper end of a clothespin graft had been torn loose from the underlying laminae, and in three the fusion had been broken directly across. Crossing of previous laminal defects seemed to be the basis of pseudarthrosis in ten instances. Of these ten cases, new pseudarthroses developed in five on attempted repair, or a failure of 50 per cent.

NEW TYPE OF REPAIR

A new type of operative procedure has been used for the few more difficult cases of pseudarthrosis (Figs. 3-A, 3-B, and 3-C). It consists essentially in denuding the laminae and the lateral margins of the articular processes, with extension of the dissection to the bases of the transverse processes on one side only (hemifusion). The medial portion of the transverse process is likewise denuded. A thin, wide flap is removed from the outer cortex of the ilium and implanted vertically on the transverse processes. Iliac strips are then placed over the denuded posterior elements of the involved vertebrae themselves, the angle between the implanted massive iliac graft and the mid-line being filled in. Wandering of the chips is prevented by the laterally placed large iliac graft. Furthermore, contact is made with the transverse processes and the outer surfaces of the articular facets, as well as across the previous spine fusion on one side. When this form of repair is used, only one side of the spinal area is dissected and one half of the pseudarthrosis area is seen. The remaining previous bony masses on the opposite side are left intact for such stability as they may already produce.

Although percentages have been indicated, too few of these operations have been done for a final estimation of their efficacy.

CONCLUSIONS

1. The percentage of pseudarthrosis developing in spine-fusion operations in the lumbosacral region may be reduced by an adequate amount of bone of good texture, firmly implanted and free from infection.

2. The possibility of pseudarthrosis should be discussed with the patient before operation in every instance, so that he is forewarned, and so that consent for repair may more readily be obtained, when necessary.

3. One should avoid covering any greater number of spinal intervals than are absolutely essential in performing a fusion at the lumbosacral juncture, but the fusion should always extend to and include the sacrum.

4. For statistical and practical purposes, it is useless to report a series of spine fusions at the lumbosacral juncture without control of the series by biplane roentgenograms, taken with the patient in flexion and extension, and with right and left bends. The roentgenograms should then be accurately superimposed. Furthermore, even with such roentgenograms, a few instances of pseudarthrosis in any series will fail to be recognized.

NOTE: The authors wish to acknowledge the assistance, in the compilation of these statistics, of Kazuo Yanagisawa, M.D., and Alfonso Della Pietra, M.D.

1. BOSWORTH, D. M.: Clothespin Graft of the Spine for Spondylolisthesis and Laminal Defects. Am. J. Surg., **67**: 61–67, 1945.

DISCUSSION

DR. JOSEPH S. BARR, BOSTON, MASSACHUSETTS: Dr. Cleveland and his associates have presented a most interesting paper on a timely and important subject. Spine fusion is an important procedure in the armamentarium of the orthopaedic surgeon. It is necessary that we re-examine all of our patients who have had fusion to determine what the percentage of failures is and to take such steps as will enable us to lower the percentage of failures. Dr. Cleveland has stated that the major causes of failure of fusion are: (1) the use of an inadequate amount of bone, (2) infection, and (3) fracture of the graft. To this list of important factors I would like to add some additional points.

1. Complete fixation of the segments to be fused, so that all motion is obliterated, should be our aim. Fixation by external means, such as plaster casts and shells and prolonged bed rest, is demonstrably ineffective, for varying amounts of motion occur, no matter what type of apparatus is used. The double clothespin graft, or H graft as I prefer to call it, is a very effective means of immediate internal fixation, and I think that where it can be used, it represents a definite advance in technique.

2. The use of screws across the facets and bone plates between spinous processes has become popular in certain clinics. There are disadvantages to the use of metals which may outweigh their advantages.

I agree with the authors' conclusions that, if the fourth lumbar space is fused, the fifth lumbar must be included. Dr. Cleveland has omitted reference to what, if anything, he does to the articular facets at the time of fusion. This is a difficult question. They can be left untouched. They can be cut across and bone grafts laid over them. They can be curetted and excised or a key graft placed across the facet, as advocated by McBride. There is room for further study of this problem. Theoretically, at least, if one succeeds in obtaining fusion of the articular facets, motion between the involved segments will be obliterated. Fractures through the neural arches may occur, however, unless additional bone is used.

I believe that careful preparation of the bed and of the facets, as advocated by Hibbs, plus the use of an H graft with additional cancellous bone from the ilium, is the most satisfactory method of fusion available today.

No matter what method is used, biplane bending roentgenograms, taken after one year, will reveal pseudarthrosis in an unpleasantly high percentage of cases. Repair of the pseudarthrosis is unnecessary in about 50 per cent. of the cases, as clinically they are asymptomatic.

I find myself in complete agreement with the authors in practically all of their major premises, and wish to congratulate them again on an excellent paper.

DR. EUGENE M. REGEN, NASHVILLE, TENNESSEE: You have heard another typical Cleveland, Bosworth, and Thompson report. The tremendous value and significance of this analysis cannot be appreciated in the short time they have had to present their findings, and I would urge their careful examination in less

hurried moments. I could profitably emphasize many of their conclusions, but the virtues of their paper are so obvious that I shall confine myself to some few questions that have arisen as I read this report.

1. A curve to indicate the incidence of pseudarthrosis year by year, as new operative procedures developed and as the surgeons improved their technique, might be enlightening.

2. No report was made on the type of postoperative care following the original fusion. It is my opinion that there now exists over the country a distinct trend toward inadequate postoperative fixation and bed rest following spine fusion. One wonders whether the prospect of a relatively short period of bed confinement may serve as an inducement for the patient to accept this major operative procedure. Since the incidence of pseudarthrosis varies inversely with the security of the fifth, fourth, and third lumbar vertebrae to the pelvis and their distance from it, I believe that this would indicate the use of adequate plaster fixation and bed confinement for from two to three months after the operation.

3. In discussing the causes of pseudarthrosis, the authors did not mention the possible influence of spinal fluid escaping after the accidental opening of the dura. All of you who have explored the spinal canal know that this is not an infrequent occurrence.

4. The authors have proved conclusively the value of biplane bending roentgenograms. They require the accurate superimposition of corresponding points on the roentgenographic films, but it is a fact that fibrous fixation alone can be secure enough to prevent the detection of motion at a given vertebral joint by the method of examination they describe.

5. The paper states that the relief of symptoms is directly proportional to the length of successful fusion above the sacrum, but the authors did not emphasize the danger of limiting a working man's usefulness by stiffening too many of his lumbar joints.

6. Since the vast majority of lumbosacral operations are performed for mechanical disorders, with or without nerve-root compression, I believe one should universally perform the fusion from the sacrum to the fourth lumbar vertebra only, unless there is a distinct indication to go higher.

7. The necessary period of postoperative fixation is usually followed by temporary stiffening of joints above the site of fusion. I routinely employ a set of simple exercises, begun three months after operation, which have materially shortened convalescence. These exercises mobilize the joints above the site of fusion, and greatly strengthen the glutaeus maximus and anterior abdominal muscles.

8. My experience does not compare with that of the authors in number of cases. My postoperative follow-up does not meet their criteria, but observation of my own patients has not revealed pseudarthrosis to be noticeably prevalent. I feel reasonably sure that it is well under the 20 per cent. which the authors report in their series.

9. Finally, even though a painful pseudarthrosis does exist, the symptoms can often be largely, if not entirely, relieved, and a secondary operation can be avoided by postural exercises which tend to remove the stress and strain from the site of abnormal joint irritation.

Dr. Alan DeForest Smith, New York, N. Y.: It has been the habit at the New York Orthopaedic Hospital to make periodic surveys of the results of fusion operations. The results in the lumbosacral cases have been comparable to those which Dr. Cleveland reported.

Our first survey showed 12 per cent. of failures at the fifth lumbar, and 20 to 30 per cent. between the fourth and fifth lumbar; and that has continued, although we have reduced the percentage to 8 at the lumbosacral joint. The failures between the fourth and fifth lumbar vertebrae still remain high. That seems to be the critical point. Internal fixation has not helped. In any case in which fusion extends above the fifth lumbar, I believe that a double spica should be used, and the patient should be confined to bed for at least eight weeks.

I was interested to see the results with the clothespin graft, and to note that they showed no difference from those cases in which other methods were used.

Dr. D. M. Bosworth (closing): This study was attended by a great deal of difficulty. We tried to divorce entirely the question of pseudarthrosis from that of recovery on a symptomatic basis.

All these fusions were done by three surgeons only. They were a control series, not done by residents, but accurately performed by careful, well-trained men. They were performed in six hospitals, so there was no variation in incidence of complications based on the type of hospital used.

The postoperative care in most of the cases has been two and one-half to three weeks of bed rest, and thereafter a lumbosacral belt reinforced with light steel. The biplane bending roentgenogram was established for the purpose of follow-up accuracy. A few cases of pseudarthrosis will be unrecognized, even with biplane bending roentgenograms. In our series, in only one instance was pseudarthrosis unrecognized by such roentgenograms. Patients securing solid fusion become free of back disability, as a rule. They do not notice loss of spine motion clinically. As to the tight graft, I know of one H graft which was placed too tightly by the surgeon.

As to the question of removal of the articular facet, the facets were usually left intact in our cases. If a large series were run without débridement of the articular facet, and the percentage remained the same as with débridement of the articular facet, we would feel that that particular procedure would not be necessary.

CARTILAGINOUS-CUP ARTHROPLASTY IN UNUNITED FRACTURES OF THE NECK OF THE FEMUR *

BY JOHN ROYAL MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

From Temple University Hospital, Philadelphia

Ununited fractures of the neck of the femur have been less frequent since the revival of internal fixation of acute fractures of the femoral neck, in 1931, by Smith-Petersen and his associates. In a recent review of 300 fractures of the femoral neck, Boyd and George report union in 86.5 per cent. and non-union in 13.5 per cent. However, ununited fractures of the neck of the femur are a greater problem today, since the revival of internal fixation, due to the fact that the head of the femur and the trochanteric area are often irreparably damaged by the internal-fixation elements themselves. It is not unusual to encounter large defects in the trochanteric area and in the head of the femur, and in many instances in the cartilage of the head and the acetabulum, which have resulted from nails, screws, or various types of pins. The employment of the bone graft in ununited fractures of the neck of the femur, as advocated by Albee and others, which was frequently used in the late 1920's and the early 1930's, is usually contra-indicated, principally because of the structural defects already referred to. Aseptic necrosis of the head continues to persist with slight, if any, reduction in its frequency, in spite of internal fixation. Absorption of the neck of the femur (both the shaft and the head fragment) is often more pronounced than formerly, due either to failure to recognize the non-union early or to persistent retention of the internal-fixation apparatus in the hope that, by a miracle, union may occur.

All of these factors play an extremely important part in the selection of the procedure to be employed in the treatment of ununited fractures of the femoral neck. The writer divides ununited fractures of the neck of the femur into three classes:

Class I: Non-union with a viable head and well-preserved neck fragments.

Class II: Non-union with a viable head and complete, or nearly complete, absorption of one or both neck fragments.

Class III: Non-union with absorption of the neck fragments and a devitalized head.

The bone graft, recommended by Albee, or the bone graft combined with internal pin fixation, recommended by Gallie, and the osteotomies suggested by Pauwels, Leadbetter, Dickson, Schanz, and McMurray, are especially suited for cases in Class I. The reconstruction operations of Brackett, Luck, and Magnuson, and similar procedures, are particularly indicated for fractures in Class II. The reconstruction procedures advocated by Whitman, Albee, Colonna, Lorenz, Smith-Petersen, Wilson, and others may be employed in the fractures of Class I, but seem particularly indicated in Class II or Class III, where loss of the neck and a "dead" head are present. All of these operative procedures are well known, and time and space do not permit a detailed description of the technique of the operations or a discussion of their relative merits.

The cartilaginous-cup arthroplasty was devised by the writer in 1938, and should be properly regarded as a modification of the Brackett operation. Wagner, in 1929, advocated removing the head of the femur, reaming out the head, and fitting it to the neck of the femur, thus restricting its use to those cases in which the distal fragment of the neck persisted.

TECHNIQUE

Briefly, the cartilaginous-cup arthroplasty consists in removing the femoral head and reaming out the osseous portion until only a cartilaginous cup with a very thin layer of

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1947.

bone (one-eighth of an inch or less in thickness) remains. The cup then readily transmits light (Fig. 4,*b*). A small section of the trochanter is elevated and reflected with its attachment to the glutaeus medius. The end of the femur is then carefully rounded off with a cup reamer and the cartilaginous cup is fitted to it. The femur with its cartilaginous cup is then returned to the acetabulum, and the greater trochanter is reattached to the lateral aspect of the shaft, two or three inches below the cup level. (Figures 1 to 6, inclusive, are illustrative of the technique.) The wound is carefully closed in layers, beginning with the capsule and following with the vastus lateralis and glutaeus medius layer, then the fascia lata, the subcutaneous tissue, and the skin. A double hip spica, extending from the ankle to the nipple line on the side being operated upon and from the knee to the nipple line on the other side, is applied. The extremity operated upon is in maximum abduction, usually from 60 to 80 degrees, with the patella pointing straight up. A minimum of 60 degrees of abduction is essential. Occasionally an adductor tenotomy is required to obtain the desired abduction.

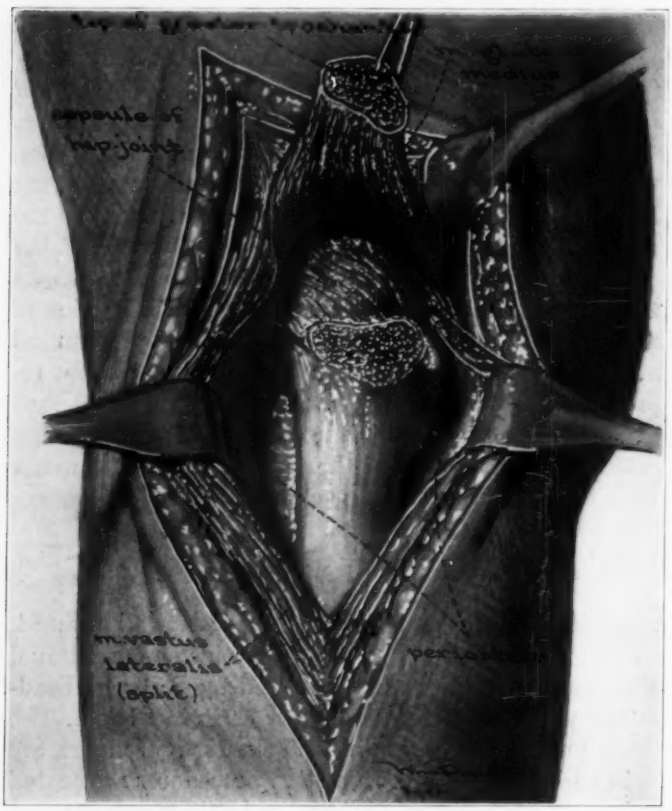

FIG. 1

The approach to the hip used in the cartilaginous-cup arthroplasty (not original).

Certain points should be emphasized in carrying out this procedure. Complete hemostasis, clamping and tying all vessels to prevent free bleeding (except from bony areas), is essential. The cup must be fitted snugly. It should be placed accurately on the end of the femur, neither in valgus nor in varus, and with neither anterior nor posterior tilting. Its position should be maintained by wide abduction; this is accomplished by abducting the femur until firm resistance is met. A double spica is essential to complete the immobilization. The foot on the side operated upon need not be included. The trochanter with its gluteal attachments must be reattached in order to ensure abduction power. It should be reattached securely, preferably with a screw, in order that early union of the trochanter and the shaft may be obtained. Closure must be done with extreme care to avoid hematoma. It is very important to ream the femoral head out thoroughly before the proximal end of the femur is rounded off, to prevent a small femoral fragment. The cup must fit very tightly; otherwise it will slip off (Case 7).

POSTOPERATIVE CARE

Movement of the ankle, foot, and knee on the side not enclosed in the cast is begun after recovery from the anaesthesia (spinal anaesthesia is employed in all cases), and is carried out hourly during waking hours. Deep breathing, likewise, is done at hourly

FIG. 3

Preparation of the trochanteric area of the femur with reamer.

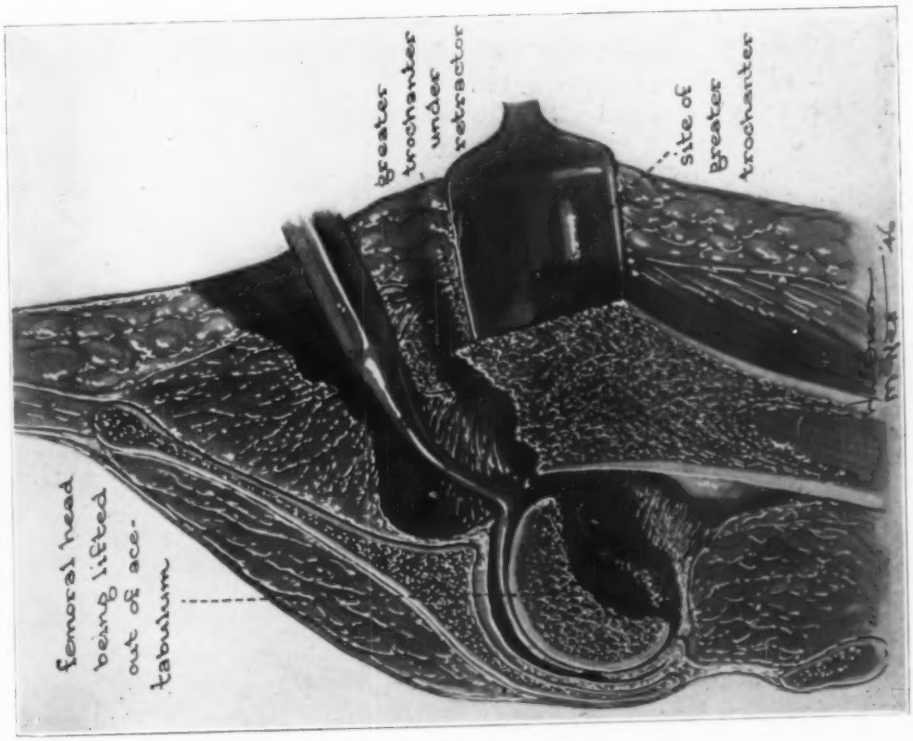

FIG. 2

Sketch of a sagittal section through the hip, illustrating removal of the head.

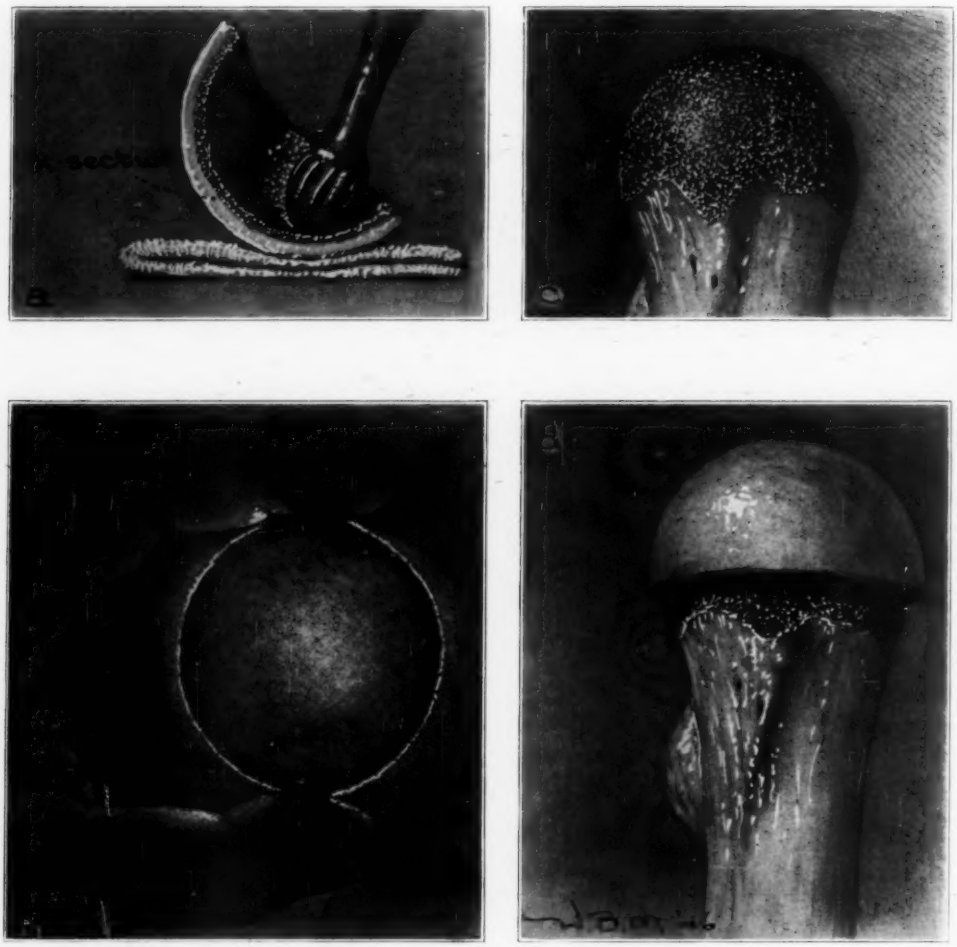

FIG. 4

Illustrates the preparation of the head, the light test, and the fitting of the head on the femur.

intervals. The patient is turned every two hours during the day and every four hours during the night. On the twenty-eighth day the back half of the plaster, on the side on which the knee is enclosed in the cast, is cut and knee exercises are done at hourly intervals until flexion of 90 degrees or better is obtained. This usually requires one or two weeks. On the forty-second day (six weeks), the thigh which was not operated upon is released. The hip spica on the side operated upon is removed at the beginning of the eighth week, and balanced traction is applied in the line of abduction. The extremity is gradually brought down to approach the neutral position. The patella must be straight up so as to avoid any external-rotation deformity. Active flexion, extension, and rotation exercises are employed during the traction period. Weight-bearing is permitted at the end of the tenth week.

By the end of the sixth month the patient usually has approximately 80 degrees of flexion, 30 degrees of abduction, 5 to 10 degrees of adduction, and 180 degrees of extension. This motion increases gradually up to one year. In case of pain in the hip or the knee on the side which has been operated upon, or a tendency to external rotation, the patient is confined to bed with a five-pound to ten-pound weight and pulley traction, until the discomfort has disappeared. A moderate abduction deformity occasionally persists as long as six months. Three centimeters of shortening may occur, depending upon the structure of the upper end of the femur. This must be rounded off until a healthy bone surface

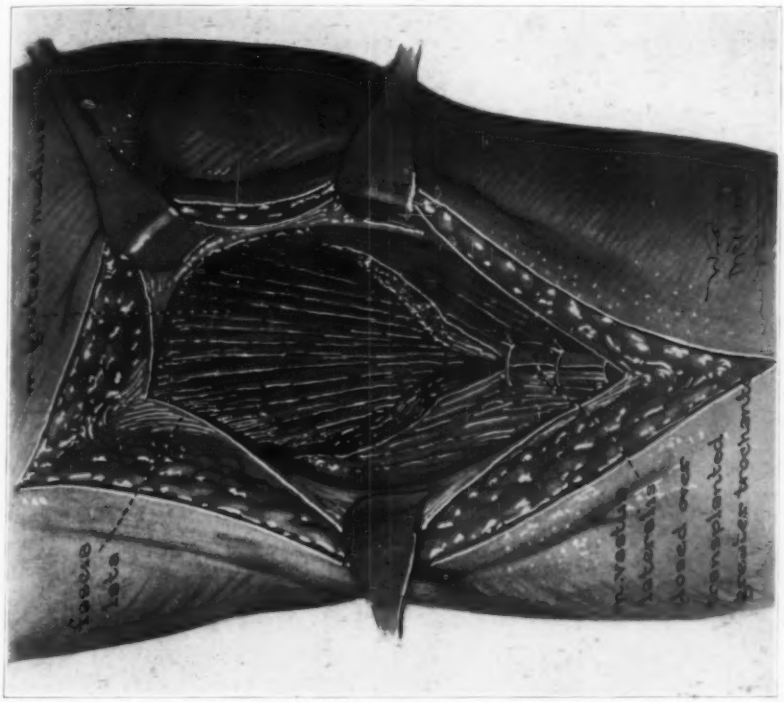

FIG. 6

Fig. 5: Shows the cartilaginous cup properly placed on the end of the femur and inserted within the acetabulum. The fragment of the trochanter is attached to the femur with a Vitallium screw. (Note that the shaft of the femur is in wide abduction.)

Fig. 6: The greater trochanter has been attached to the shaft of the femur. The vastus lateralis is approximated and sewed to the soft parts overlying the trochanter and to the muscle sheath of the glutaeus medius. (This is similar to the technique of Colonna.)

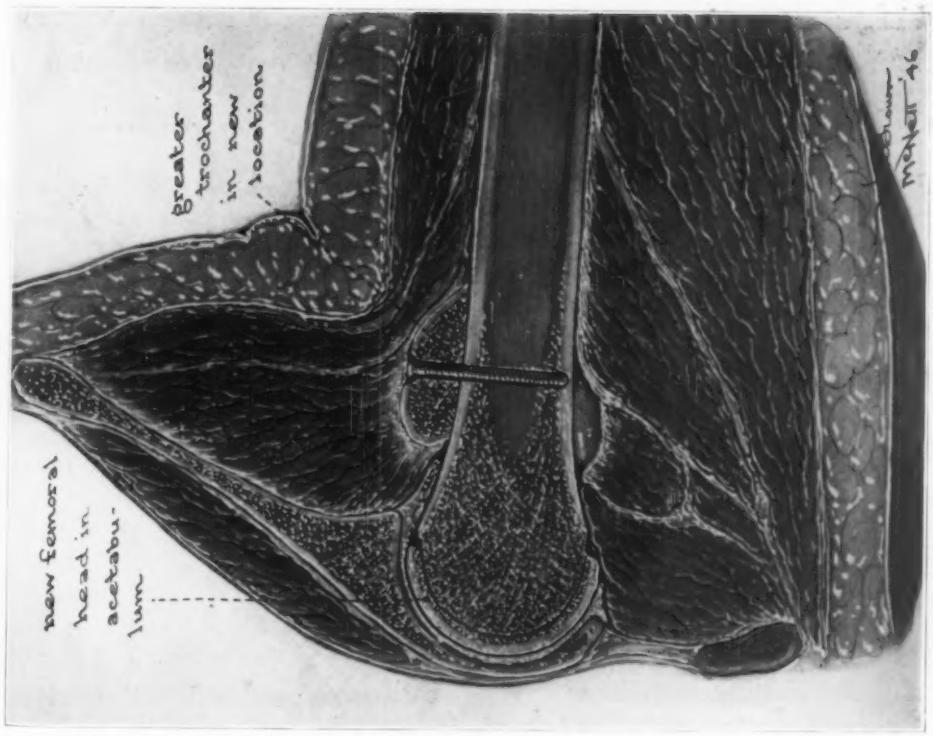

FIG. 5

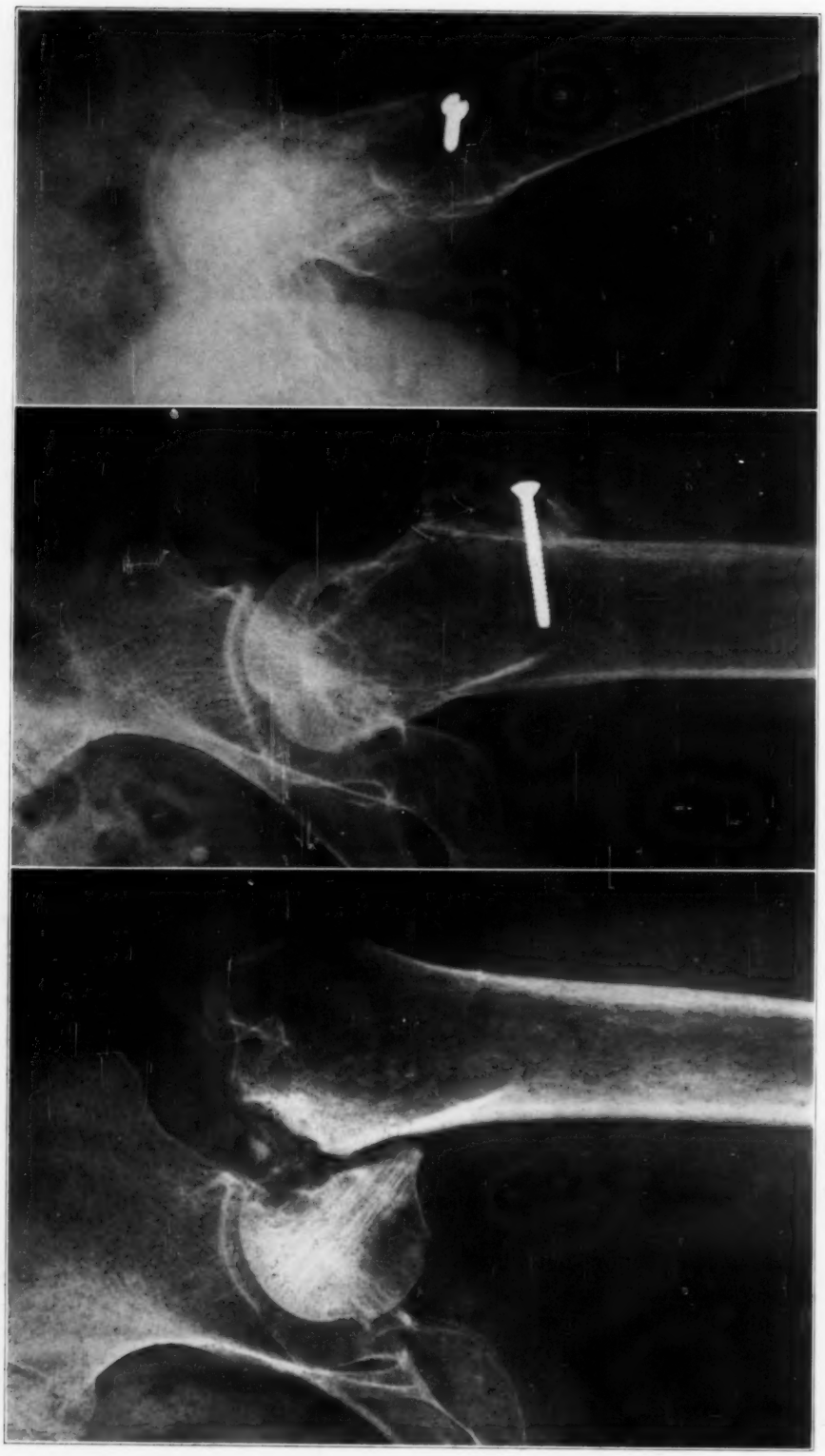

FIG. 7-A FIG. 7-B FIG. 7-C

Fig. 7-A: A. J. Ununited fracture of the neck of the femur (January 24, 1946).
Figs. 7-B and 7-C: Anteroposterior and lateral views of cartilaginous cup after fifteen months (May 5, 1947).

for contact with the head is encountered, thus causing the shortening. Shortening of less than two centimeters is not compensated for by an elevation of the heel, as the tilt of the pelvis compensates for the loss of the neck angle and maintains the acetabulum in a favorably tilted position, thus offering the best assurance of stability in this type of procedure.

RESULTS

The cartilaginous-cup arthroplasty has been performed in nineteen cases in Class II and Class III, from 1938 until June 1947. Eleven of the nineteen cases have been followed from one to nine years.

The majority of the patients were women, ranging in age from forty-four to seventy-seven years. Nine of the cases are considered to show excellent results. M. S. (Case 4) is considered to have had a fair result, in spite of the slight pain and the continued use of a cane, because he is happy and contented, and leads a normal life. Y. W. (Case 7) is regarded as a poor result, even though pain is very slight when a cane is employed. The patient works daily and earns her own living. Shortening averaged one to three centimeters, the majority of patients having two centimeters or less. The characteristic findings in early and late cases are illustrated in Figures 7-A through 10-C.

The majority of the patients complained of mild stiffness when they arose in the morning or after prolonged sitting. This disappeared after activity and, although regarded skeptically as an early sign of degenerative arthritis, it has offered no problem to date in any of the patients in the group.

COMPLICATIONS

Among the nineteen cases reviewed, there were three deaths. One patient, P. G. H., died twenty-one days after operation, and a pulmonary embolism was found at post-

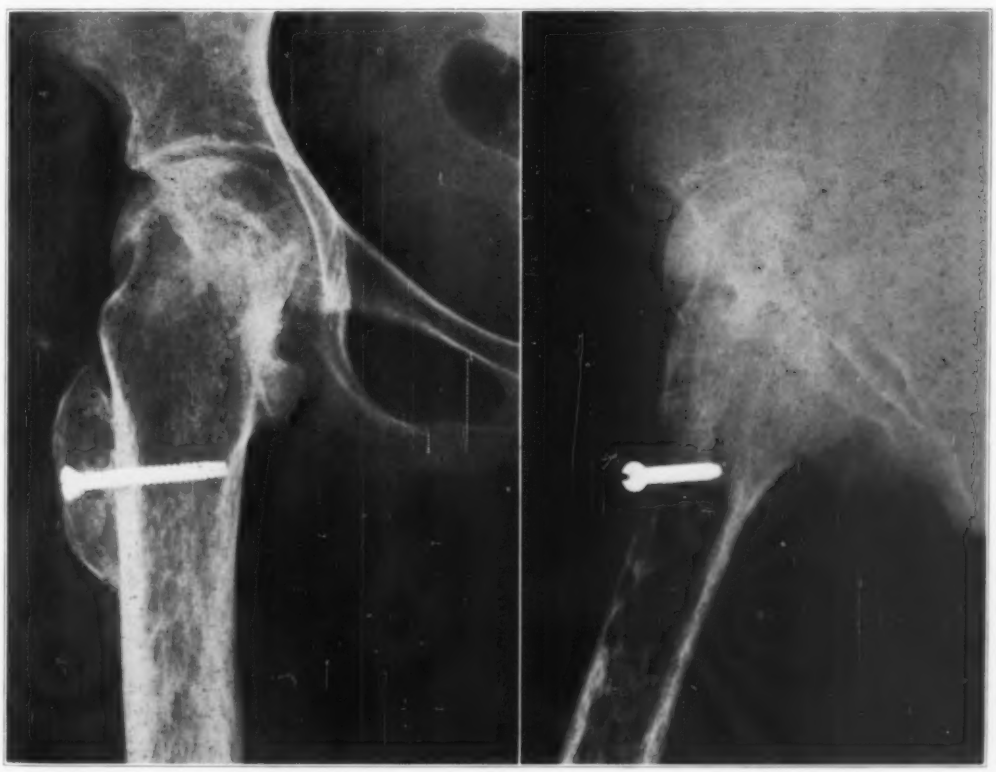

FIG. 8-A FIG. 8-B

Anteroposterior and lateral views of cartilaginous cup, five months after operation.

FIG. 9-A FIG. 9-B FIG. 9-C

Fig. 9-A: E. W. Ununited fracture of the neck of the femur (December 19, 1944).
Figs. 9-B and 9-C: Anteroposterior and lateral views of cartilaginous cup, twenty-five months after operation (April 29, 1947). This is one of the early cases, and an attempt was made to sew the trochanter to the underlying soft parts. Note marked improvement in this regard in the more recent cases, as shown in Figs. 7-A, 7-B, and 7-C, and in Figs. 8-A and 8-B.

shown in Figs. 7-A, 7-B, and 7-C, and in Figs. 8-A and 8-B.

FIG. 10-A

FIG. 10-B

FIG. 10-C

Fig. 10-A: A. M. Ununited fracture of the neck of the femur (January 5, 1938).
Figs. 10-B and 10-C: Anteroposterior and lateral views of cartilaginous cup (July 26, 1946). In this early cartilaginous-cup arthroplasty, the trochanter was poorly attached (sewed in position). The end result was excellent (see Tables I, II, and III and Figs. 10-D and 10-E).

FIG. 10-D

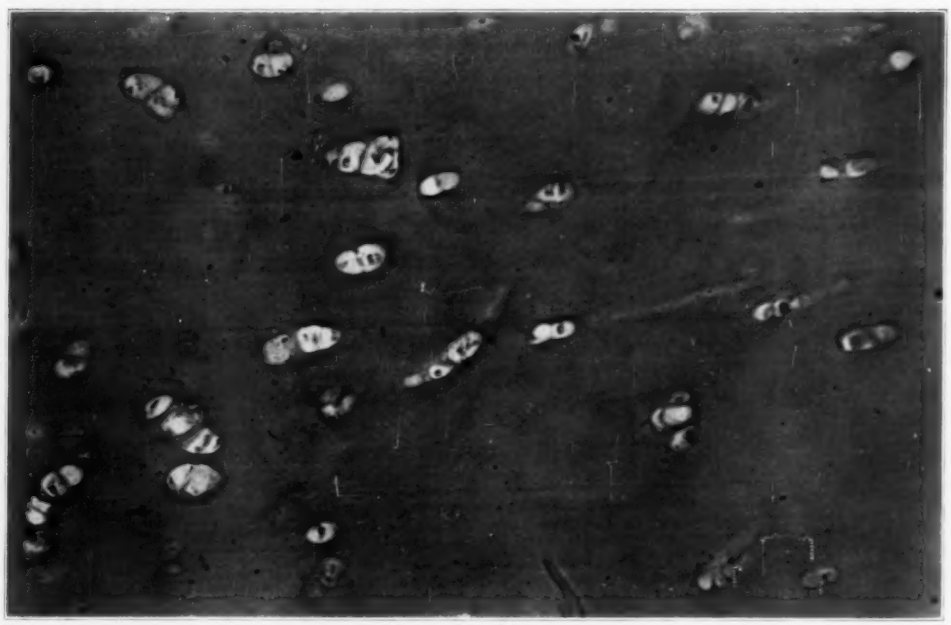

FIG. 10-E

Description of microscopic findings by E. E. Aegerter, M.D.: "One section was removed from the weight-bearing portion of the head of the femur. The articular surface of this bone is covered with a layer of cartilage, measuring approximately five millimeters in thickness. The hyaline matrix is homogeneous and appears to be normal in quality. There is a normal distribution of lacunae throughout this fragment of cartilage, and the cells within the lacunae appear to be normal. Directly beneath this cartilage is adult bone. There is no recognizable epiphyseal line and no evidence of new-bone formation. Between the rather coarse spicules are a few marrow cells, interspersed between considerable amounts of fat. Diagnosis: normal hyaline articular cartilage."

mortem examination. A second patient, S. T., died six weeks after operation, of a cerebral accident. The third patient, A. M., died nine years after a cartilaginous-cup arthroplasty,

TABLE I

FOLLOW-UP STUDIES AFTER OPERATION

Case	Patient	Sex	Age	Postoperative Period (*Years*)	Presence of Pain
1	A.M.	Female	63	9	None
2	A.F.	Female	72	7	None
3	A.R.	Female	72	7	None
4	M.S.	Male	63	6	Slight
5	A.McC.	Female	49	3	None
6	S.S.	Male	51	3	None
7	Y.W.	Female	53	3	Pain present
8	E.W.	Female	44	2	None
9	E.R.	Female	77	1	None
10	A.J.	Female	44	1	None
11	S.O.S.	Female	69	1	None

TABLE II

RANGE OF MOTION ONE YEAR AFTER OPERATION

Case	Extension-Flexion (*Degrees*)	Internal Rotation-External Rotation (*Degrees*)	Abduction-Adduction (*Degrees*)
1	190–110	30–30	45–45
2	180–90	10–10	30–15
3	180–90	30–30	45–45
4	180–90	30–10	20–10
5	180–80	30–10	15–30
6	180–90	20–20	30–20
7	195–110	10–30	45–30
8	190–110	30–30	30–30
9	180–60	10–45	30–0
10	180–90	30–10	20–10
11	180–90	15–30	30–20

of carcinomatosis. High-power and low-power microscopic sections of cartilage, taken from the head of the femur in this case, are shown in Figures 10-D and 10-E. A fourth patient, A. McC., has multiple sclerosis and has been confined to bed and to a walker since the second year after operation. There have been no operative deaths. In Y. W. (Case 7) the cartilaginous cup slipped off during the first three weeks, due to a poorly fitting head and lack of adequate abduction. This patient has a painful hip and degenerative arthritis, with a very thin joint line.

DISCUSSION

The cartilaginous-cup arthroplasty, first performed in 1938, differs from the Brackett operation, primarily, in that the head of the femur is converted fundamentally into a cartilaginous cup. The procedure was first performed with a good deal of trepidation, due primarily to the fact that the consensus of the investigators was that hyaline cartilage would not survive transplantation. A reasonable questioning of this impression was permissible because of the amazing restoration of the hip to practically normal motion, with a negative Trendelenburg sign and the absence of limp, and the appearance of a good joint line. The continuance of excellent joint motion and the absence of limp seemed to justify repetition of the procedure. This patient died in 1947, nine years after the operation,

and a section of the cartilage from the head of the femur was obtained (Figs. 10-D and 10-E). The pathologist's report * is as follows:

"A section, removed from the weight-bearing portion of the head of the femur, is covered with a layer of hyaline cartilage, measuring five millimeters in thickness. The hyaline matrix is homogeneous and appears

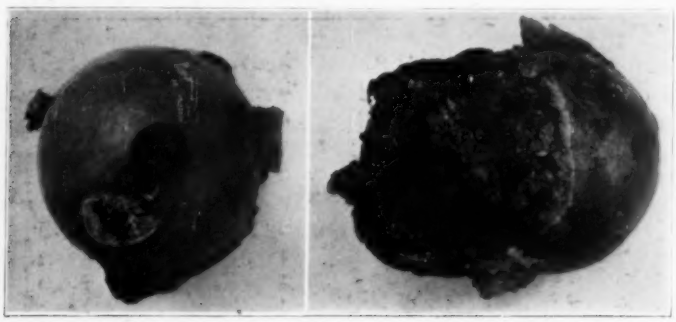

FIG. 11-A FIG. 11-B

Fig. 11-A: A cephalic view of a cartilaginous cup, three weeks old. (Patient died of pulmonary embolism.) The cartilage is blood-stained. It is firmly attached and could not be removed by vigorous twisting.

Fig. 11-B: A lateral view of the same cartilaginous cup. Note the blending of the cartilage with bone.

FIG. 12-A

Fig. 12-A: Shows a six-week-old cartilaginous cup, attached to shaft. This was so firmly attached that manual manipulation could not pull it loose.

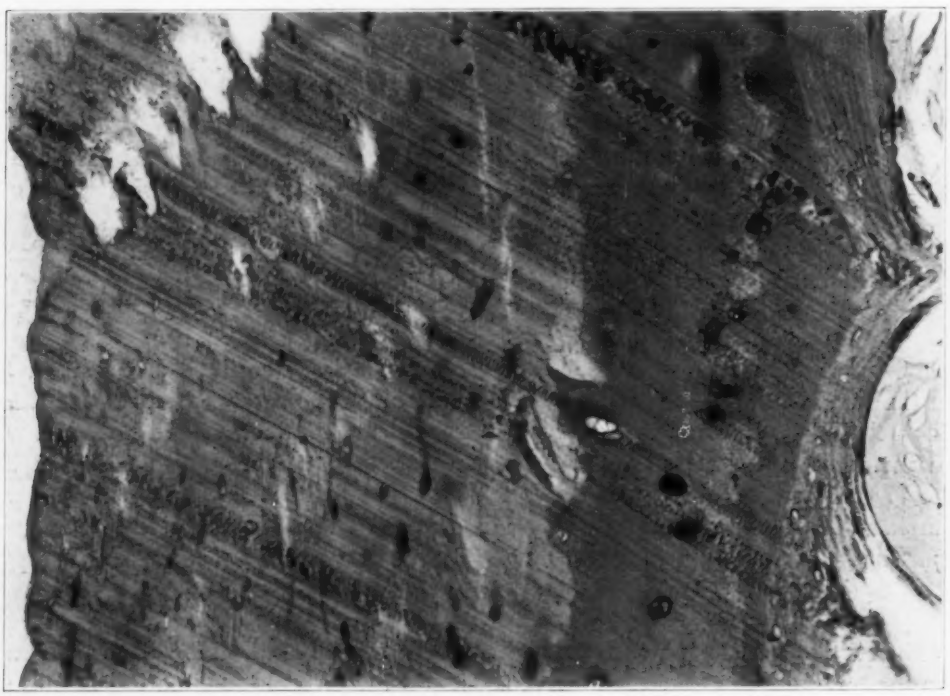

FIG. 12-B

to be normal in quality. There is a normal distribution of the lacunae throughout this fragment of cartilage, and the cells within the lacunae appear to be normal. Directly beneath this cartilage is normal adult bone. A section taken from the non-weight-bearing portion of the femoral head shows a layer of cartilage which is indistinguishable from that described above. Sections from the acetabular rim show the usual fibrillar cartilage with attachment of adult bony tissue. Diagnosis: normal hyaline cartilage."

* Made by E. E. Aegerter, M.D., Professor of Pathology, Temple University Medical School, Philadelphia, Pennsylvania.

FIG. 12-C

FIG. 12-D

Figs. 12-B, 12-C, and 12-D: Description of microscopic findings by E. E. Aegerter, M.D.: "Sections from the surface of the head of this femur in the weight-bearing area show it to be covered by a layer of cartilage. The outer two-thirds of this tissue shows no evidence of living chondroblasts, but in the inner third lacunae are present and one can find viable cells. This suggests that the outer two-thirds had undergone cell death, but that the inner third has been preserved. Along the inner surface of this cartilaginous layer the bony spicules conform to the contours of the cartilage. . . . At one side of the section there is a considerable amount of fibrous tissue and provisional bone, which appears to be arising from the under-cartilaginous layer. One might conclude that this process has developed secondary to the implantation of the cartilage. Diagnosis: viable cartilage."

A second patient, P. G. H., died six weeks after operation. The head and neck of the femur (Fig. 12-A) were obtained for study. From the description of the microscopic findings (Figs. 12-B, 12-C, and 12-D), it will be noted that the superficial cartilage appears dead, while the deep layers of cartilage are alive. Furthermore, "along the inner surface of this cartilaginous layer the bony spicules conform to the contours of the cartilage. This would suggest that some osteogenesis has caused an arrangement of the bone lamellae which is most efficient for stresses in this area. At one side there is a considerable amount of fibrous tissue and provisional bone, which appears to be arising from the under-cartilaginous layer. One might conclude that this process has developed secondary to the implantation of the cartilage."

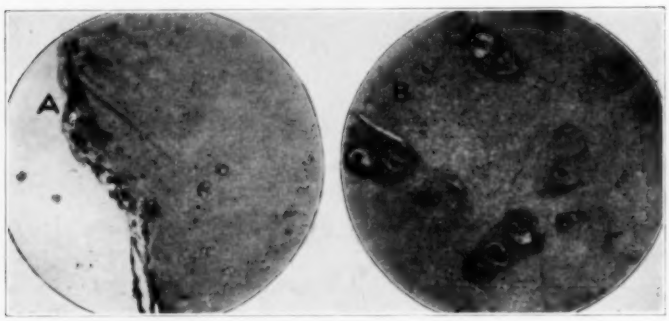

FIG. 13

Low-power microscopic section of a twenty-year-old autogenous rib-cartilage graft (used by John Staige Davis to repair a saddle depression in the nose). Graft became distorted and one-third of the transplant was removed twenty years later by Dr. Lyndon A. Peer. Note normal cartilage in old graft. (Reproduced, by permission of the American Medical Association, from *Archives of Otolaryngology, 42:* 386, 1945.)

Figures 11-A and 11-B represent a cartilaginous cup, three weeks old, taken from a patient who died of pulmonary embolism. The large defect present in the head was caused by the nail used in the internal fixation. The head was securely attached and could not be pulled off by manual efforts. Unfortunately, the microscopic sections were lost before they were read. The early bony attachment of the cartilage to the head in this case and in that of P. G. H. (Figs. 12-A to 12-D) is the basis for the relatively early mobilization in the after-care. There is undoubtedly a long gap between the specimens observed nine years and six weeks, respectively, after operation, but it is quite probable that the older case may have had similar development.

The fact that normal hyaline cartilage was found in these cases does not prove, of course, that all of the other patients reported in this series have hyaline-cartilage regeneration. However, the clinical and roentgenographic findings strongly suggest the possibility that they are following a like course.

Lyndon Peer, in an article published in 1938, stated that Paul Bert, about 1865, was probably the first to transplant hyaline cartilage. Bert concluded that cartilage grafts retain their viability. Fischer, in 1882, reached the conclusion that cartilage grafts would survive if transplanted with perichondrium. Loeb, in 1926, transplanted xiphoid cartilage with perichondrium in the same guinea pig (autografts) and in different guinea pigs (homografts). The autograft survived, with practically no reaction about the graft. The homograft survived, but with a lymphocytic reaction which usually reached its peak at the end of twenty-one days. Mannheim and Zypkin, in 1926, performed fifty experiments with autografts of hyaline cartilage, and concluded that the cartilage retained its specific structures in all cases and that autocartilaginous grafts formed good material for plastic repair. König, in 1896, was the first to use cartilaginous transplants in human beings. He employed cartilaginous grafts in the repair of laryngeal and tracheal cartilage defects. Von Mangoldt, in 1899, successfully transplanted costal cartilage to the nose. Most of the pioneer work in hyaline-cartilage transplantation has been performed by the otolaryngological and plastic surgeons. Davis, in 1917, and Gillies, in 1920, emphasized particularly the viability of hyaline-cartilage autogenous grafts and the practical value of these grafts to surgery. Lyndon Peer, from whose work the historical review is largely quoted, presented, in 1945,

TABLE III

CLINICAL FINDINGS

Case	Trendelenburg Test	Presence of Limp	Amount of Shortening (*Centimeters*)	Use of Brace, Crutches, or Cane	X-ray Evidence of Degenerative Arthritis	Condition of Head
1	Negative	None	1	None	None	Live
2	Negative	None	2	None	Plus-minus	Dead
3	Negative	None	1	None	None	Live
4	Negative	Slight	1.5	Cane	None	Dead
5	Negative	None	1.4	Walker *	None	Live
6	Negative	None	3	None	None	Dead
7	Positive	Marked	2	Cane	Plus	Dead
8	Negative	None	2	None	None	Live
9	Negative	Slight	2	None	None	Dead
10	Negative	None	2	None	None	Live
11	Negative	None	1.5	None	None	Dead

* Multiple sclerosis was present in this case.

microscopic sections taken from a twenty-year-old hyaline-cartilage graft (Fig. 13), which had been employed by John Staige Davis in the repair of a saddle nose. Slight buckling had necessitated partial excision; hence a specimen of the twenty-year-old transplanted cartilage was obtained. It proved to be normal hyaline cartilage. This work and that of Fisher, Carter, Loeb and Siebert, Logan, Hills, O'Connor, Falconer, and others point rather conclusively to the value of autografts of hyaline cartilage.

Sherman and Phemister, in 1947, published a paper on the pathology of ununited fractures of the neck of the femur and concluded that, if the blood supply of the head is cut off, the head dies and the articular cartilage becomes necrotic. The cartilage remains unaltered until the blood supply reaches it, and is then replaced by either an imperfect type of fibrocartilage or by bone. This excellent piece of work casts considerable doubt upon the value of the cartilaginous-cup arthroplasty. However, the historical data as well as the clinical and roentgenographic findings reported in this article, particularly the findings in the nine-year-old cartilaginous cup in Case 1 (A. M.), point to the contrary. In the eleven cases reported in this series, the head was completely removed from the acetabulum in each case. In two instances there was slight bleeding; in the other nine, no bleeding occurred. Unfortunately, no bone sections or cartilage sections were studied at the time of the cup arthroplasty, so that there is no microscopic evidence as to which head was dead and which was viable. Six cases showed roentgenographic evidence of a dead head; the remainder, viable heads (Table III). The complete removal of the head certainly deprived the cartilage of all blood supply.

It is hoped by the writer that this presentation will stimulate thought on hyaline-cartilage autografts. Their possible application to smaller joints, particularly those of the hand and foot, seems practical. The writer has under observation at this time a number of old congenital club feet upon which reconstructions have been performed through the usual approach of a triple arthrodesis. The cartilaginous surfaces were reapplied after the desired bony reconstruction was done. Movement in these joints, instead of fixation, has been obtained. The results to date in several cases (after one year of follow-up) have been striking. This material will be analyzed and reported after adequate time for proper analysis has elapsed.

Homografts have been utilized by the plastic surgeons, and cartilage banks have been established for a long time. Perhaps cartilage banks will be a part of the orthopaedic surgeon's armamentarium in the near future.

CONCLUSIONS

The cartilaginous-cup arthroplasty has been proposed as another method for handling ununited fractures of the neck of the femur, particularly those in Classes II and III. The method is admittedly a modification of the Brackett procedure and is similar anatomically to the methods described by Wagner; Venable, Stuck, and Beach; and others. Its originality, if there be any, is based primarily upon the utilization of the hyaline cartilage of the head of the femur as an autograft transplant. The results in nine cases are considered excellent, and two are poor.

NOTE: The writer wishes to thank J. T. Ealy, M.D., and John Ashby, M.D., Residents in Orthopaedic Surgery at Temple University Medical School; Luke W. Jordan, M.D., Associate in Orthopaedic Surgery; and E. E. Aegerter, M.D., Professor of Pathology at Temple University Medical School, for their valuable assistance in the preparation of this paper.

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DISCUSSION

DR. JOSEPH A. FREIBERG, CINCINNATI, OHIO: I was fortunate in seeing Dr. Moore's first case, a nine-year result, last fall. Those of us who saw this woman were really amazed at the excellent restoration of function. Because of my impression of this case, and on the basis of what Dr. Moore told us, I decided to carry out the procedure in the next case that presented itself. I have done the operation in two cases. Unfortunately, neither one was an ideal patient for a reconstruction operation, but I am satisfied with the results. Before I show lantern slides of these patients, I want to mention one or two facts.

First, Dr. Moore did not state that, when you have the head in your hand and are reaming it out with the burr, the head has a tendency to get away from you. This happened to me on one occasion, and I could not be persuaded to put it back. I finished this operation as a Whitman reconstruction. This hip is progressing at about the same rate as though an arthroplasty had been performed.

The second criticism is the difficulty of putting the cartilaginous cup back on the neck at the original angle. If this is not done, the hip-joint relations are permanently disturbed. The cartilage cup should be replaced as accurately as possible. In two of Dr. Moore's cases, one four months and the other five months after operation, there is limitation of extension. Neither one of these was an ideal case. In the moving picture which Dr. Moore has showed, there appeared also to be some limitation in extension, as in the last case.

I wish to show the slides of my cases: This man, aged fifty-two, had had a left hemiplegia in 1944 and a fracture of the femur, treated elsewhere with traction, which resulted in non-union. He came in because of the non-union. He had a contracture of the knee of about 15 degrees, as well as some flexion contracture of the hip. From the postoperative roentgenogram, it appears that the head is not so well placed on the neck as it might be. This is a point which Dr. Moore brought out. In the lateral view the head has not slipped. The amazing thing is the firmness with which the cup was fitted at the time of operation. We did not have any difficulty in keeping it from being displaced. This man is shown four months after his operation. He is exceptionally well pleased with the result. He walks on crutches, with limited weight-bearing. He has now 70 degrees of motion, but he still has some flexion contracture and limitation of extension of the hip to 15 degrees. Clinically, he appears to have an excellent result.

This second man, aged fifty-five, had a fracture of the neck of the femur. He was treated elsewhere, and non-union resulted. The head appeared to be viable. He had a full-thickness tibial graft and a Smith-Petersen nail reconstruction, done in January 1947. He complained of pain. It was not an ideal case for reconstruction. This roentgenogram was made in June 1947, five months after operation. There is one screw in the shaft. The patient has slight limitation of motion. He is putting some weight on the leg, with crutches. He now has 60 degrees of flexion in the hip.

I do not believe that the end results in my cases are as good as those in Dr. Moore's cases, but I am satisfied with them so far.

Dr. Paul C. Colonna, Philadelphia, Pennsylvania: Although I have not had any personal experience with this operation, the results shown here are very impressive in the treatment of selected cases of non-union of the neck of the femur. Technical difficulties may occur in reaming out some of these femoral heads, however.

The technique described by Dr. Moore presupposes that one is dealing with viable articular cartilage. Unfortunately, many of these loose heads present marked evidence of damage which has been produced by misplaced pins and nails,—not infrequently cartilaginous degeneration or areas of fibrillation. In addition, certain cases present ischaemic or avascular necrosis of the entire loose head. In these instances, it is difficult to say whether any portion of the head fragment should be used. In those cases in which the head fragments cannot be salvaged, other types of reconstruction operation are desirable.

Certain cases present narrowing of the joint space, indicating cartilage destruction. At times there is arthritis, and these cases are best treated by arthrodesis.

However, this still leaves a number of old ununited fractures of the hip with a viable head and a normal joint space, for which this operation may be ideally suited.

This operation, which might be called a modification of the Brackett operation, could have a far wider application than the author has described,—for instance, the utilization of the articular cartilage to produce an arthroplasty. If it is possible to restore function by using the joint cartilage over the head of the femur, why cannot joint cartilage be used in other joints? Will it be possible to restore function by preserving the articular cartilage of many joints by the use of cartilage banks, as we are doing today with bone banks, utilizing both heterogeneous and autogenous grafts?

I would like to compliment Dr. Moore on finding another method for treating non-union and, more important, for using the principle he has illustrated in the restoration of joint function. This may be the answer to many of our problems in the reconstruction surgery of joints.

Dr. I. William Nachlas, Baltimore, Maryland: It has been the concept of arthroplasty that one good articular surface is all that you need to get good motion. Are the beautiful end results that we saw in these illustrations the result of saving that cartilaginous cup, or are they the results of the superb technique that Dr. Moore has used?

Dr. M. N. Smith-Petersen, Boston, Massachusetts: I have had no experience with this procedure. I think that the principle of reconstruction may be a little different from what Dr. Moore thinks it is. He showed some beautiful slides of a "new head". I question whether the "cartilaginous cup" actually survives as an articular surface. In my opinion, the cartilaginous cup surrounded by a blood clot is exposed to the acetabulum, which acts as a mold. The blood clot undergoes metaplasia and is gradually transformed into hyaline cartilage. This, then, is new hyaline cartilage, and the photomicrographs will probably show the cartilage cells running parallel to the joint surface rather than perpendicular, as they do in normal hyaline cartilage.

I believe, then, that the principle is really that of mold arthroplasty.

Dr. John R. Moore (closing): The use of homografts of hyaline cartilage is not new. They have been employed by the plastic surgeons and the rhinolaryngologists for many years. The possible application of homografts of hyaline cartilage to orthopaedic surgery is primarily the purpose of this presentation. Cartilage banks may be part of the armamentarium of the orthopaedic surgeon in the future.

MANAGEMENT OF CHRONIC OSTEOMYELITIS SECONDARY TO COMPOUND FRACTURES

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In World War II early, adequate surgical care, rapid evacuation, and the use of chemotherapeutic and antibiotic agents made possible early closure of compound wounds by delayed sutures. The number of cases of osteomyelitis developing from compound fractures was, therefore, creditably small. Delayed primary or early secondary closure was not attempted in all cases. Many wounds were healed or almost healed by the time the men reached a permanent installation. In other cases, closure was not attempted, because of the severity of the infection or the multiplicity and extent of the wounds. Furthermore, delayed closure of compound fractures was not always successful. Whatever the cause of failure, a considerable number of patients with chronic osteomyelitis were returned to the Zone of Interior. These presented a real problem in reconstruction, varying from the patient with a small draining sinus and a small bone cavity to those with extensive soft-tissue destruction and great loss of bone substance.

It seemed imperative, therefore, that a method of therapy be used that would lead to rapid healing of the infection and would include provision for bone replacement and final wound closure.

Two methods of obtaining early healing of the osteomyelitis had been established:

1. Healing of the infection by the application of skin grafts, following débridement and saucerization, as advocated by Lord (1902), Reid (1922), and Armstrong and Jarman (1936).

2. Débridement and saucerization with soft-tissue obliteration of the dead space and primary wound suture, proposed by Dickson, Diveley, and Kiene in 1941 and by Key in 1944.

Satisfactory results have been obtained with both methods.

Kelly, Rosati, and Murray, using an improved technique and aided by chemotherapy, advocated healing of the osteomyelitis, after débridement and saucerization, by a split-thickness skin graft.

The principles set down by Kelly and his associates, with some alteration in technique, were instigated at the Gardiner General Hospital by Lieutenant Colonel Frank West and Captain Charles Stebbins. This method was successful in healing practically all of the cases of chronic osteomyelitis, although in a few cases more than one operation was required. Three of the patients reported here required more than one operation before complete healing occurred (Table I).

The problems presented, therefore, were:

1. When and in what cases of chronic osteomyelitis could this method be used?
2. How much tissue should be removed at the time of débridement and saucerization?
3. How soon after débridement and saucerization should a skin graft be applied?
4. What should be done after healing of the infection?
5. What is the method of management of these cases?

Débridement and saucerization, followed by split-thickness skin grafts, may be used in any case of chronic osteomyelitis, when the acute cellulitis has subsided and the general condition of the patient is satisfactory.

At the time of débridement, all dense scar should be removed so that healthy wound edges remain. At times it is impossible to take out all the scar surrounding the infected

TABLE I

SKIN-GRAFTING WITH 100 PER CENT. TAKE *

Time	No. of Cases
7 to 10 days	9
14 days	5
21 days	6
28 days	11
29 to 59 days	8
More than 60 days (failures)	3
Total	42

* In three cases new grafts were applied, with successful results; in two cases pedicle grafts were used.

area, but failure to do so may cause difficulty in the final closure of the wound. The scar is prone to become ulcerated at the time of the skin-graft closure. All foreign material must be removed. This includes shell fragments, pieces of clothing, and metal used for internal fixation of the fracture.

All dead and infected bone must be removed, and as much dense sclerotic bone adjacent to the infected bone should be removed as possible, care being taken not to destroy useful bone, down to healthy appearing bleeding bone. Where large granulation areas exist about the fracture, these may be decreased by a skin graft to improve the condition of the patient, but it is useless to apply a skin graft or flap to a sinus or ulcer with infected bone beneath. This bone must be cut away to prepare an adequate bed for the graft or other type of wound closure.

Therefore, at the time of débridement and saucerization, one should not be concerned

FIG. 1-A

FIG. 1-B

Fig. 1-A: Before débridement and saucerization.
Fig. 1-B: After débridement and saucerization.

FIG. 1-C

FIG. 1-D

After healing with skin graft.

FIG. 1-E

FIG. 1-F

Fig. 1-E: Final closure of wound after healing of third stage.
Fig. 1-F: Obliteration of bone cavity with block of iliac bone.

with the problem of closure of the wound, but should be aggressive enough to proceed to healthy tissue, both skin and bone. The saucerization must be good so that, if possible, no pockets or ledges are left, as their presence increases the difficulty of application of skin grafts. The skin graft should be fashioned to fit into each pocket and crevice of the bone (Figs. 1-A to 1-F, inclusive).

At the same time one should be cautious not to remove bone unnecessarily, so that

a dehiscence or a pathological fracture results. Reinforcing a weak bone, as brought out recently by Carpenter, Rosenfeld, and Mech, is not such a formidable procedure as replacement of large bone defects. However, if it appears that complete interruption of the bone is necessary to remove all dead tissue, then this should be done; otherwise failure of closure will result. We see, then, that not to do enough leads to poor results, and to go too far produces prolonged disability and major surgical repair. Following débridement and saucerization in the cases of osteomyelitis in which the wound is packed open, an interval of five to seven days should elapse before application of a split-thickness skin graft. The authors prefer to wait seven days. The packing may be removed on the sixth day, and a wet dressing of normal saline may be applied before the graft.

With complete healing of the skin graft and closure of the osteomyelitic focus, there is a steady decrease in the size of the defect. Surrounding skin is easily loosened by massage and active exercises. Also, there is active proliferation of connective tissue beneath the grafts, so that the pocket becomes shallower. The filling out of the pocket has been described by Lord, Reid, and others. They gave this as a reason for leaving the skin graft as a permanent covering. The authors found that, at the time of removal of the graft, there was a distance of one to one and one-half inches between the skin and the bone. It is our feeling that contracture of this scar tissue, with resultant circulatory embarrassment, is the most important cause of the ulceration and recurrence of infection.

After healing of the infection, some previously ununited fractures united. It is important that they be properly splinted during this stage, as union occurred in one of our cases quite rapidly after closure of the wound, while splinting was inadequate, so that angulation occurred and an osteotomy was necessary.

With sufficient solid bone and a small skin pocket, no further surgery is needed. However, the lesion must be so located as to be free from trauma. The majority of patients treated by débridement, saucerization and split-skin grafts alone were left with a skin pocket, which tended to collect dirt and was prone to break down. They also had déficient remaining bone. We feel that the bone pockets should be filled, both for stability and because this scar-filled pocket is subject to vascular change and necrosis.

The average duration of the osteomyelitis was nine and one-half months; the shortest duration was two and one-half months, and the longest twenty-five months. The average patient had already had four operations; one patient had had eleven operations and the wounds had all healed by the procedures outlined.

Considerable attention should be paid to the general condition of the patient. Good results depended to some extent upon how well the patient's condition could be improved with diet, vitamins, and blood before the operation. All were cases of long standing, and the patients had had several surgical procedures and had traveled long distances. The majority had been bedfast from the time of injury. Sulfonamides were occasionally used, when the patients had sensitivity to penicillin; otherwise, penicillin alone was used. Starting forty-eight hours before operation, 20,000 units was administered every three hours until fourteen days after operation.

All sequestra were carefully removed. Sclerotic eburnated bone was also removed down to healthy bleeding bone, and care was given to fashioning a saucerization so that no unnecessary pockets or overhanging ledges were left. The tourniquet was then released and active bleeding was controlled. Oozing was given a little time to decrease, and the cavity was packed with fine mesh gauze, soaked in glycerine. After trying a large variety of materials, Captain Stebbins found that glycerine was preferable in that it did not macerate the tissue and it allowed separation of the pack without damage to the granulation tissue. It could be removed and a skin graft could be applied without a preliminary wet dressing. However, most wounds were dressed prior to skin-grafting, and wet dressings were applied. After packing of the wound, a plaster cast was applied.

From the fifth to the seventh day the wounds were inspected. If found to be clean,

TABLE II

SITE OF INFECTED FRACTURES

Bone Involved	No. of Cases	Total
Femur		
Upper third	1	
Lower third	6	
Middle third	6	13
Tibia		
Upper third	7	
Lower third	3	
Middle third	10	20
Humerus		
Upper third	3	3
Ilium and sacrum		1
Foot		5
Total cases		42

a split-thickness skin graft was sutured to the wound edge, and was packed carefully into the bone defect with cotton soaked in glycerine. The packing was done meticulously until above the level of the skin. This was then covered with fine rubber tissue to prevent drying and hardening, and a pressure dressing was applied. Where stability was required, a cast was also applied. Seven days after operation the dressing was changed, the cotton was removed, and all necrotic portions of the graft were trimmed away. The results of skin grafts, in the forty-two cases in which the end results are reported, are shown in Table I.

In no case was a skin graft applied at the time of saucerization, as in about seven days a thin granulation tissue develops over the raw bone and facilitates the ability of the graft to take.

The final or third stage consists in removal of the skin graft, obliteration of the bone defect with a bone graft, and closure of the wound. Of the cases treated thus, forty-two were followed for at least six months; these are reported. Table II shows the location of the lesion. Cultures were taken routinely but were of little clinical value, as the gross appearance of the wound determined whether or not it could be closed.

After the wound had healed, some fractures united. This is desirable and worth waiting for. Oedema subsided with wound healing, and the size of the defect decreased. Gentle massage loosened the remaining healthy skin, so that final closure could be done many times without shifting skin flaps. We felt that the danger of a flare-up of infection after the bone graft should decrease with time. The general condition of the patient improved. He gained weight, became ambulatory, and began to overcome atrophy, so that better results from the bone graft were assured.

After several months, however, either because of trauma of use or constriction of the scar, the grafts were prone to become ulcerated, which delayed the final operation. Therefore, the authors feel that twelve weeks is about the optimum interval before the final operation. In this series, the average interval was fourteen weeks, the longest being thirty-two weeks and the shortest five and one-half weeks.

Prior to the final stage, careful attention must again be paid to the preoperative condition of the patient. Blood transfusions were found to be more important than penicillin for the success of the operation. By the fifth day after operation, in spite of multiple transfusions at the time of surgery and afterward, the total serum protein was low, particularly the globulin fraction. This caused considerable concern as to the patient's ability

to combat his infection. Penicillin was stopped in several cases at the end of the seven days, when sutures were removed; the wound seemed healed at that time, but drainage developed a few days later. Therefore, the penicillin was continued for fourteen days.

The final or third stage involves the usual preoperative preparation. With the use of a pneumatic tourniquet, the skin graft was dissected from the skin margin. Then it was easily shelled out of the bone cavity in one piece. The bone bed was freshened with a chisel, the tourniquet was removed, and the wound was packed, while a bone graft was being obtained. In this way the bleeding had subsided by the time of application of the graft, and the hematoma was decreased. Cancellous-bone chips were used in all bone cavities. Iliac bone from which a major portion of the cortex had been removed seemed best, but some cavities were so large as to require all available bone to fill them. Where the

FIG. 2-A

FIG. 2-B

Fig. 2-A: Appearance of wound after débridement and saucerization.
Fig. 2-B: Following healing of osteomyelitis with split-thickness skin graft.

FIG. 2-C

FIG. 2-D

FIG. 2-E

Figs. 2-C and 2-D: Appearance of bone cavity after healing with split-thickness skin graft (Fig. 2-C) and after packing with bone chips (Fig. 2-D).
Fig. 2-E: Final appearance after obliteration of bone cavity with cancellous-bone chips.

defect in the bone was shallow, a block of iliac bone was used. In a few cases with large bone loss, repair was done with sliding and onlay cortical grafts, fixed with metal screws. In cases with bone cavities, the bed was merely freshened to bleeding bone. No attempt was made to drill about the area or to open the medullary canal.

Where non-union existed, the medullary canal was opened in all cases. The bone ends were freshened and, where extensive sclerosis was present, multiple drilling was done. The wounds were then closed in layers, wherever possible without drainage (Figs. 2-A to 2-F, inclusive).

FIG. 2-F

Wound and bone graft after final closure.

Several patients required shifting of skin flaps for closure, and wounds on the feet were closed with tubed pedicle grafts which had been put in place prior to bone-grafting. After closure, casts were applied in all cases requiring additional stability. Pressure dressings and Thomas splints were used in those with sufficient bone strength.

In twenty-six or 61.9 per cent. of the cases, the wounds healed by first intention following the use of bone grafts. Three or 7.1 per cent. of the cases had slight drainage from a portion of the wound, but without cellulitis or deep infection; these wounds healed within four weeks and remained healed. In four or 9.5 per cent. of the cases, postoperative drainage developed; these wounds healed within eight weeks and remained healed. There was no evidence of deep infection or of sequestration; the bone united.

In four or 9.5 per cent. of these cases, superficial drainage developed and continued for as long as sixteen weeks before final healing occurred. No sequestration occurred. The wounds remained healed as long as we were able to follow the patients (about six months). The exact healing time is not known; the wounds were found to be healed after removal of the casts, which were changed about every four weeks.

In five or 11.9 per cent. of the cases, healing failed to occur. In one patient revision of the wound edges was done, followed by complete healing. One wound healed after a split-thickness graft had been applied to a superficial ulcer on the margin of the wound. The osteomyelitis recurred in three cases and the entire process had to be started again. The end results in these three cases were not known, because this work was stopped, owing to the closure of the Hospital. A number almost equal to that reported was not included, because the patients were still in the process of treatment at the time the Hospital was closed.

We see, then, that in twenty-six cases, or 61.9 per cent., the wounds healed by first intention and remained healed. Their bone grafts also appeared to be healed when last seen. Eleven or 26.2 per cent. had postoperative drainage from hematomata or necrosis of the wound edges, but healing occurred without further surgery, sequestration, or bone grafts. Healing occurred in two cases after revision of the wound edges. Three cases, or 7.1 per cent., were failures.

SUMMARY

The authors feel that the management of osteomyelitis secondary to infected compound fractures should consist in débridement and saucerization, with closure of the wound by primary suture, if it can be done without excessive tension. Otherwise, the method of delayed closure by split-thickness skin grafts should be used.

After healing of the infection, union will occur in many cases of previous non-union.

Many patients need no further surgery after wound healing because of adequate remaining bone, and because the bone and skin pockets are small.

With non-union, large bone defects, or large bone and skin pockets, and in those cases in which reinforcement is required for stability, three months should elapse after complete healing of the wound before bone-grafting is done.

The use of cancellous bone, from which as much cortex as possible has been removed, is recommended. If the defect is large, it may be difficult to obtain sufficient bone without the use of cortical chips. The authors have had no experience with bone grafts at the time of débridement and saucerization, but this seems to be the next step in evaluating the management of chronic osteomyelitis.

Careful preoperative and postoperative preparation with antibiotics and blood transfusions is essential.

As postoperative drainage appeared to result from hematoma, which was prone to become infected, it is suggested that delayed primary closure of the wounds would give a higher percentage of complete early healing.

The authors see no reason why chronic osteomyelitis of hematogenous origin could not be managed in a similar way.

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A SURGICAL PROCEDURE FOR LYMPHOEDEMA OF THE EXTREMITIES

A Follow-up Report*

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Many cases of lymphoedema, irrespective of the cause of lymph stasis, progress to the point of disability as a result of the development of recurrent cellulitis and lymphangiitis, or the enlargement of the extremity to elephantine proportions, or a combination of both. The more disabling complication, recurrent cellulitis and lymphangiitis, frequently produces severe general reactions, sometimes of an alarming nature.

Although it is not the purpose of this paper to discuss the etiology of lymphoedema, it seems appropriate to offer the general impression of many authors concerning the cause of recurrent cellulitis and lymphangiitis.

Sabouraud and Unna first called attention to the possible etiological significance of the Streptococcus in cases of progressive lymphoedema associated with erysipelas-like attacks. Unna further explained the periodic attacks on the basis of incomplete healing of the original lesion, which results in a vascular disturbance and an incomplete destruction of the streptococcus. Reichert, in 1929, stated, "Simple lymph edemas are the result of stasis. Add the factor of infection and we have an entirely different picture, that of elephantiasis. Chronic infection, usually caused by a streptococcus, after a time, readily leads to a progressive hypertrophy of the hypodermal and dermal connective tissues. . . . Simple mechanical blockage of the lymphatics causes regional lymph edema, but the characterictic fibromatosis, and the histologic changes peculiar to elephantoid states, cannot be produced without pyogenic infection."

Halsted, in 1921, demonstrated that radical excision of the axillary glands or axillary vein, or both, will not, in itself, produce this condition. To produce elephantiasis of the upper extremity, there must also be a secondary infection. To support this contention, there have been reports by such authors as Stevens, Homans, Drinker, Field, and their co-workers [4, 5, 6, 12]. In some instances, these reports have been supported by laboratory experiments.

In 1940, Ochsner, Longacre, and Murray, in a very excellent and comprehensive review of the literature on the subject of lymphoedema, concluded that, "Elephantiasis is the end result of recurrent erysipeloid lymphangiitis, produced by pyogenic infections, usually the streptococcus. Lymphedema is a predisposing factor for the pyogenic infection which causes the inflammatory reaction which is responsible for the ultimate fibromatosis."

The pathological changes which accompany the late stages of lymphoedema, in the cases comprising this report, have consisted of replacement of the adipose tissue by enlarged lymph spaces and fibrosis of the connective tissue. In two of the patients, the skin and subcutis were thickened, and inflammatory changes were noted, together with an inflammatory process; one of the patients presented gangrenous areas in the skin. In those patients in whom a biopsy of the muscle was made, no pathological changes were noted.

Operative procedures for the treatment of disabling lymphoedema were initiated by Lisfranc early in the nineteenth century by a scarification procedure, according to Keysser. Carnochan in 1851 ligated first the femoral and then the external iliac arteries; many amputations resulted. Handley, Lexer, and Lanz based their methods of treatment on attempts to establish lymphatic drainage. These procedures ended in failure.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1947.

In 1912, Kondoléon, with the same thought in mind, attempted to establish communication between the superficial and the deep lymphatics by the excision of strips of deep fascia, and by placing subcutaneous tissue in contact with the muscle. Matas was the first surgeon to perform such a procedure in this country. The Kondoléon treatment was disappointing in most instances and led to modification by Sistrunk, Auchincloss, Ghormley and Overton, and others. These modifications of the Kondoléon operation were based on a more extensive removal of skin and subcutaneous tissue, which primarily reduced the size of the limb, but failed in many instances to delete the recurrent cellulitis and lymphangiitis and to maintain the postoperative decrease in the size of the extremity.

Other operative approaches have been described by Gillies and Fraser and by Pratt and Wright. These operations consist in transplanting or turning down pedicle skin grafts in a bridgelike fashion, across the trunk to the lower extremity, in order to establish communication between the lymphatics of the leg and those of the trunk. Homans has devised a procedure in which the subcutaneous tissue is excised, but thin skin flaps, which have a very thin layer of subcutaneous tissue, are retained. After excision of the lymphoedematous tissue, these thin skin flaps are sutured into position. He felt that, since the leg was the chief reservoir of fluid, there was no reason to carry the procedure higher than the knee; and that following his complete operation on the leg, the enlargement of the thigh was reduced.

The procedure which prompted this paper was first described in the Staff Proceedings at the Mayo Clinic on January 24, 1940. The first operation had been performed on a lower extremity in May 1939. In the original report, it was stated that the abnormality seemed to be confined entirely to the subcutaneous tissue, since the underlying structures appeared normal, and that the procedure was based on eradication or excision of the diseased tissue, or, at least, excision of the most offending part of the disease process. This observation, that the diseased tissue is primarily subcutaneous, has been borne out over a period of seven years, with the exception of the two cases in which there were inflammatory and circulatory changes throughout all layers of the skin. The absence of recurrent cellulitis and lymphangiitis following this operative procedure supports the contention that recurrent cellulitis and lymphangiitis are a result of recurrent pyogenic infection or a "flare-up" of it in a previously sensitized tissue.

The surgical procedure to be described should be confined to the area below the knee and possibly below the elbow. In none of the patients on whom this procedure has been performed, has cellulitis been observed to extend above the knee; therefore, it would seem that the disabling recurrence of this disease is not only due to a pyogenic infection, but is limited to the area below the knee and is usually confined to the subcutaneous tissue.

In the series of seven cases covered by this follow-up report, four of the patients had had recurring cellulitis and lymphangiitis over a period of years. In none of these has there been a recurrence of cellulitis in the extremity operated upon. Six of these seven cases may be classified as lymphoedema praecox (Allen's classification), and in four of these recurrent cellulitis and lymphangiitis developed as a late complication ten, seventeen, twenty-three, and thirty-eight years, respectively, after the initial evidence of lymph stasis. In two of these six patients, the operation was performed because of progressive enlargement of the lower extremity. The seventh patient had extensive lymphoedema of the forearm, resulting from a lymphangioma in the arm and axilla.

SURGICAL PROCEDURE

The surgical procedure to be described is, unfortunately, not the complete answer in the treatment of lymphoedema. However, it is felt that it is an advance in the right direction, since it does eliminate the disabling feature of recurrent cellulitis and lymphangiitis and maintains the postoperative decrease in the size of the leg.

In lymphoedema above the knee, recurrent cellulitis has not been observed, and the

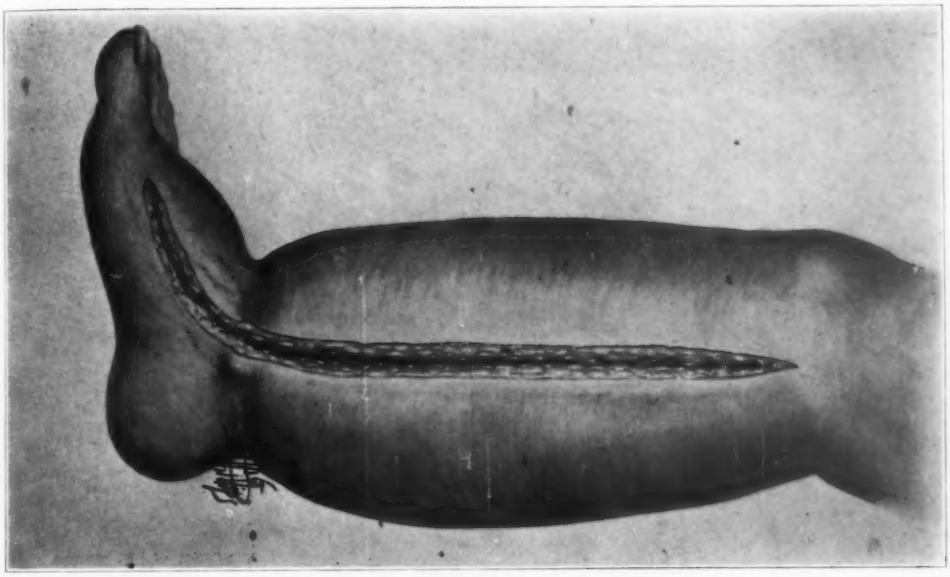

FIG. 1

Schematic drawing, showing the skin incision in the leg.

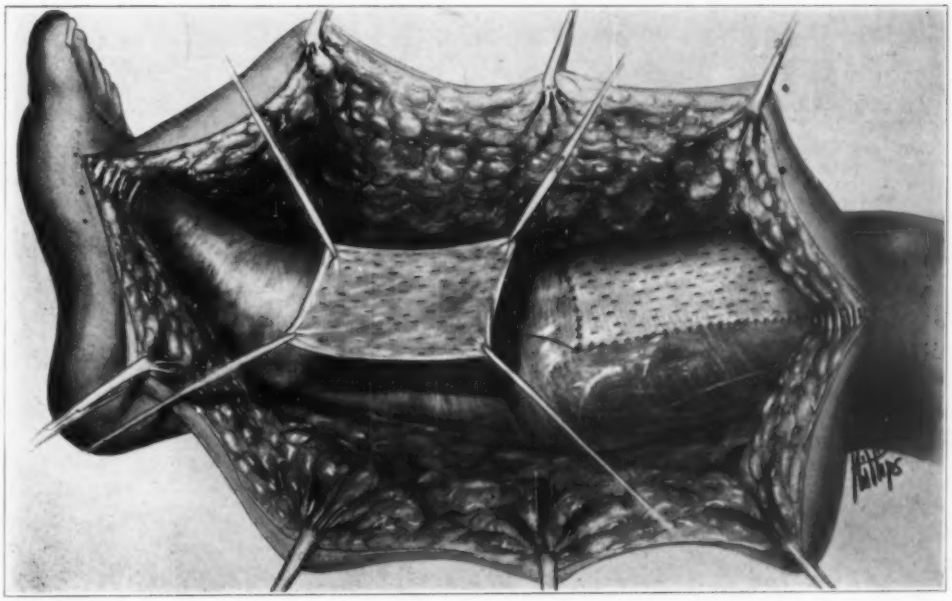

FIG. 2

Schematic drawing, showing subcutaneous dissection of the diseased tissue and the application of split-skin grafts over the muscle sheaths and peritendinous structures.

aim of treatment above the knee is to prevent incapacitating proportions of the thigh. However, it is possible that the enlargement of the thigh may be relieved by some plastic procedure such as the bridging operations of Gillies and Fraser or Pratt and Wright, or by a more simple procedure. We have been able to maintain a satisfactory decrease in the size of the thigh by the use of a thigh support after the operation on the leg.

As a preliminary to the operative procedure, the extremity should be elevated for a period of two days and drained of most of the lymphoedematous fluid. If cellulitis is present, a sulfonamide preparation or penicillin (preferably the latter) should be used two

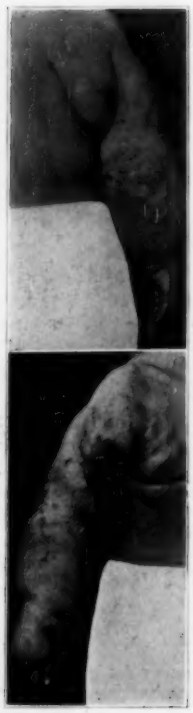

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Extensive lymphoedema of right arm before operations. (Reproduced, by permission of the Mayo Clinic., from *Proc. Staff Meet., Mayo Clin.*, **15:** 50, 1940.)

Figs. 3-B and 3-C: Appearance of right arm of patient seven years after excision of the lymphoedematous tissue and skin-grafting.

to three days preoperatively and continued postoperatively until the second procedure of the operation is completed. If no cellulitis is present, penicillin is not needed preoperatively, but is given postoperatively. At the time of the operation and before the tourniquet is applied, it is well to remove sufficient skin from the thigh for grafting, or to place the tourniquet high enough so that it does not interfere with the removal of these skin grafts from the thigh. Skin grafts may be removed from the leg, if the skin of the leg is uninvolved in the disease process. The operation is divided into two stages; either the medial or the lateral aspect of the leg is chosen for the first stage (Fig. 1).

The technical procedure of the operation is difficult to describe. An incision is made through the skin, subcutaneous tissue, and fascia, extending from the knee to the base of the toes and curving over the malleolus. At the level of the malleolus, dissection is carried posteriorly and distally, so as to approximate the upper margin of a low-quarter shoe. A fine network of areolar tissue or perimuscular and peritendinous tissue is left over the muscles and tendons, which are the recipient areas for the grafts. A thin layer of subcutaneous tissue is left over the periosteum. The grafts are placed beneath the elevated subcutaneous tissue and fascia and are sutured into position. The subcutaneous lymphoedematous tissue is then closed over the skin grafts. It is well to place multiple puncture holes in the grafts, since the recipient area is avascular, and it is thought that some nourishment to the graft may be furnished by the overlying subcutaneous tissue through the puncture holes (Fig 2). No drains are used; a firm compression dressing is applied. On the seventh to ninth postoperative day, the overlying subcutaneous tissue is excised, and the subcutaneous tissue adjoining the margins of the graft is removed by undermining; thus a somewhat flat closure of the adjacent skin and the margins of the skin graft is permitted. In no instance have these transplanted, buried grafts failed to take in their entirety. The grafts are supported

by elastic bandages, extending to the knee, for a period of ten to twelve weeks postoperatively. It is not thought advisable to proceed with the second stage until four months have intervened.

In the one case of lymphoedema of the upper extremity in which this treatment was employed, the procedure was completed in one stage. An incision was made over the dorsal aspect of the forearm and extended from the elbow to the heads of the metacarpal

FIG. 4-A FIG. 4-B FIG. 4-C

FIG. 4-D FIG. 4-E FIG. 4-F

Figs. 4-A, 4-B, and 4-C: Appearance of extensive lymphoedema of right lower extremity before surgery.

Figs. 4-D and 4-E: Appearance of right lower extremity six years after excision of lymphoedematous tissue and skin-grafting on the medial aspect of the leg, and eighteen months after excision of lymphoedematous tissue and skin-grafting on the lateral aspect of the leg.

Fig. 4-F: Appearance of the posteromedial aspect of the thigh of patient eighteen months after excision of lymphoedematous tissue and skin-grafting.

FIG. 5-A

FIG. 5-B

FIG. 5-C

Fig. 5-A: Appearance of the left lower extremity, showing cellulitis and lymphangiitis in patient who had had a previous, extensive, modified Kondoléon operation.

Figs. 5-B and 5-C: Appearance of left lower extremity after excision of lymphoedematous tissue on inner aspect of the leg. Photograph also shows type of postoperative support used for the thigh.

bones. The lymphoedematous subcutaneous tissue was dissected from the muscles of the forearm in a complete encircling manner. A fine network of fibrous tissue was left over the muscle bellies and tendon sheaths to prevent their adhesion to the skin grafts. Split-skin grafts were then removed from the thigh, transplanted, and sutured into position. The subcutaneous lymphoedematous tissue was then closed over the skin graft without drainage, and was not disturbed for ten days. The lymphoedematous tissue was then excised. The patient's recovery was uneventful, and the result was excellent. In one case, in a lower extremity, the entire procedure was done in one stage, but such extensive surgery is not recommended.

Unfortunately the postoperative appearance, as would be anticipated, is one of scarring; and, in the lower extremity, the skin grafts have shown changes associated with stasis, which have resulted, the author believes, from the avascularity of the recipient site and the dependency of the lower extremity. However, the grafts may be maintained in good condition by the daily use of a softening hand cream. This change has not occurred in the one case in which the operation was performed on the forearm,—probably because of less dependency and the absence of the function of weight-bearing.

RESULTS

Of the seven cases reported in this series, five of the patients have had excision of all of the lymphoedematous tissue below the knee, and one patient has had only the first-stage procedure on the medial aspect of the leg. One patient had lymphoedema of the upper extremity and has had complete excision of the diseased tissue below the elbow, combined with skin-grafting. In this instance of excision and skin-grafting of the upper extremity, the result was excellent.

Of the six patients in whom the lower extremity has been treated, four have had excellent results. In one of the two remaining patients, superficial ulceration in the graft developed; and, from correspondence, this is thought to have been due to changes asso-

ciated with stasis. However, prior to surgery, the involvement of the lymphoedematous extremity was so extensive that the patient was invalided from cellulitis and superficial gangrenous changes in the skin. Since surgery she has been active, and the postoperative decrease in the size of the extremity has been maintained. In spite of her improved condition, she cannot be considered as having obtained a satisfactory result. In the remaining case, a long follow-up was not obtainable. At the end of one year, the skin grafts were in good condition and the elephantine proportions of the extremity had been relieved.

CONCLUSIONS

A surgical procedure, which has been used in a small series of cases, has eliminated recurrent cellulitis and lymphangiitis by excision of the diseased tissue that results from lymph stasis; the postoperative decrease in the size of the extremity has been maintained.

The results in these cases would support the belief that recurrent cellulitis and lymphangiitis, associated with lymphoedema, are produced by a recurrent pyogenic infection.

It is felt that recurrent cellulitis associated with chronic lymphoedema is confined to the tissue below the knee, and is best treated by excision of the disease-bearing area and by skin-grafting.

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DISCUSSION

Dr. Ralph K. Ghormley, Rochester, Minnesota: I believe Dr. Macey deserves full credit for the development of this operation. The treatment of lymphoedema has been by no means satisfactory. My own impression, from what I have seen of this operation and some of the results, is that it is probably the operation of choice where there is extensive skin damage. The young woman who comes to you with early lymphoedema and wants to be cured without any deformity presents a most difficult problem. I believe that with Dr. Macey's operation you can reduce the size of the leg, but you cannot promise a satisfactory cosmetic result in the mild case, seen early. I think the Homans operation offers better results than the others developed up to now. I feel that where you have good skin, the Homans operation should be performed. It is, in my hands, a simpler operation with much less risk than Dr. Macey's.

I want to congratulate Dr. Macey on the conception and development of this procedure.

Dr. Daniel C. Elkin, Emory University, Georgia: Lymphoedema of the extremities is a surgical problem of vital importance, because of the progressive disability which the condition produces. The recurrent episodes of cellulitis and lymphangiitis, with the associated pain in the extremity, malaise, and elevations of temperature, result in great economic loss and give rise to annoying, unpredictable, recurrent illnesses. Many patients are in constant fear of these attacks of illness. A minor abrasion or excoriation of the skin in such an individual will frequently precipitate the recurrence of the infection.

Patients who have an enlargement of the extremity without skin changes are frequently not receptive to the idea of a radical operation, such as that reported by Dr. Macey. In these individuals, a satisfactory result may be obtained through excision of the involved fibrous connective tissue below the knee. In these instances, the subcutaneous tissue is so completely removed that the remaining skin is, in effect, a full-thickness skin graft. In a two-stage operation, the subcutaneous tissue of a patient's leg was completely excised except in the anterior and posterior mid-line. Satisfactory results were obtained.

With the continued enlargement of the extremities which almost invariably occurs, particularly in those instances in which there are recurrent infections, the extremity may attain elephantine proportions. At this stage, the skin usually becomes thickened, vesicle formation is frequent, and the skin becomes rough, corrugated, and horny in appearance. Such an extremity is disabling, not only because it is the result of recurrent infection, but also because the actual enlargement of the extremity interferes mechanically with its function. In many instances it may be so disabling that gainful employment is precluded. Extensive involvement of the skin, ulceration, fissure formation, and serous exudation from recurrent vesicles render such an extremity unsuitable for the operation described above. In such patients, the cosmetic deformity is of no consideration, and the procedure of total removal of the diseased tissue with skin-grafting is desirable.

It is well to stress that this procedure should be performed with utilization of a pneumatic tourniquet, since large quantities of blood will be lost in the dissection of the large masses of subcutaneous tissue. The electrocoagulation current has also been found to be a valuable adjunct in expediting the procedure.

Dr. Macey is to be commended for the excellent results he has obtained in the treatment of this disabling condition.

FRACTURES OF THE LOWER END OF THE HUMERUS IN CHILDREN *

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Attention was directed to a study of fractures of the elbow because certain of these fractures, although well reduced, result in pain, stiffness, and occasionally some deformity. The belief has been prevalent that residual disabilities do not follow well-reduced fractures of the lower end of the humerus in children, barring soft-tissue damage.

On the orthopaedic service of the Children's Hospital, fractures of the elbow occurring during the past decade or more were studied to evaluate the factors involved. It was found that some general conclusions might be drawn concerning the treatment and possible complications of these fractures.

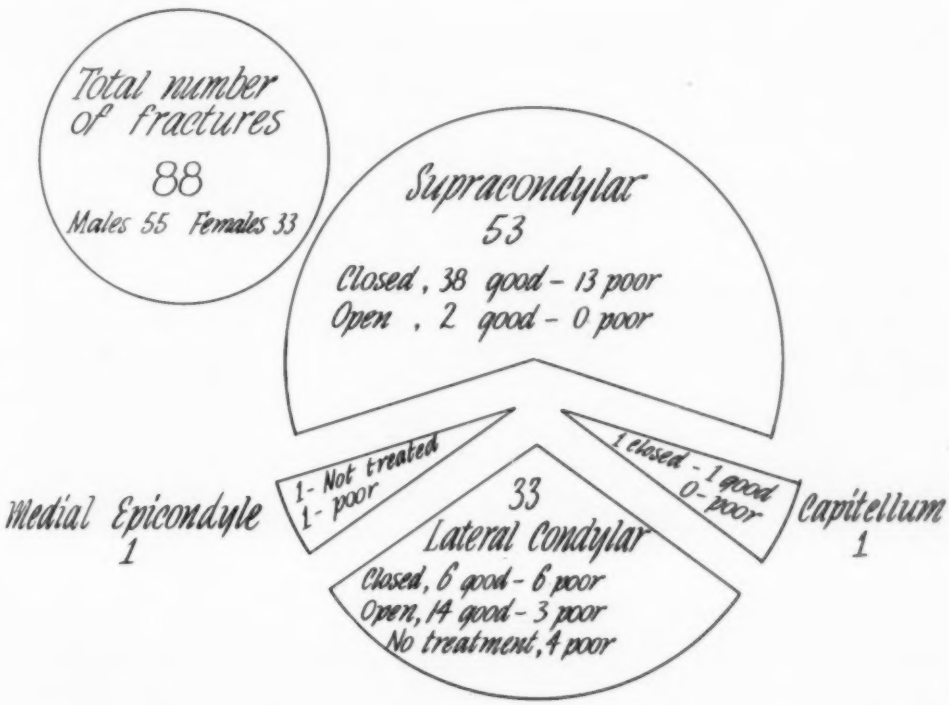

FIG. 1

Follow-up of functional results in group of fractures.

This discussion will be limited to supracondylar fractures and fractures of the lateral condyle, capitellum, and medial epicondyle. Although much has been written about fractures of the elbow involving the epiphyses, these injuries do not receive the attention they deserve. Brewster and Karp have pointed out that in 40 per cent. of fractures of the lateral epicondyle and capitellum, the end results are poor.

The elbow is a ginglymus joint, capable of flexion and extension. It, therefore, presents the following characteristics: (1) convex and concave bony surfaces; (2) muscle masses anterior and posterior to the bones to flex and extend the elbow; (3) a lax capsule anteriorly and posteriorly to allow these movements; and (4) strong collateral ligaments to limit medial and lateral motion.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 28, 1947.

A general knowledge of the anatomy, osseous development, and roentgenographic interpretation of the elbow region is essential to evaluate this group of fractures.

The lower end of the humerus is flattened from the anterior to the posterior aspects, is set obliquely, and is lower medially than laterally; thus the "carrying angle" is made. The lower articular end of the humerus is formed by two articular surfaces: laterally, the capitellum is adapted to the head of the radius, and, medially, the trochlea fits the trochlear notch of the ulna. The capitellum is spheroidal and articulates with the disc-shaped radial head. In extension, the distal portion is in contact with the radial head; in flexion, the anterior surface is in contact with it. The posterior aspect of the capitellum does not articulate, and on one side it blends with the lateral epicondyle. The margin of the radial disc articulates with the lateral lip of the bobbin-shaped trochlea, and helps to prevent medial displacement of the radius. The trochlea itself articulates with the ulna.

The epiphyseal line separating the trochlea, capitellum, and lateral condyle from the diaphysis runs transversely just above the lateral condylar cartilage. It is, therefore,

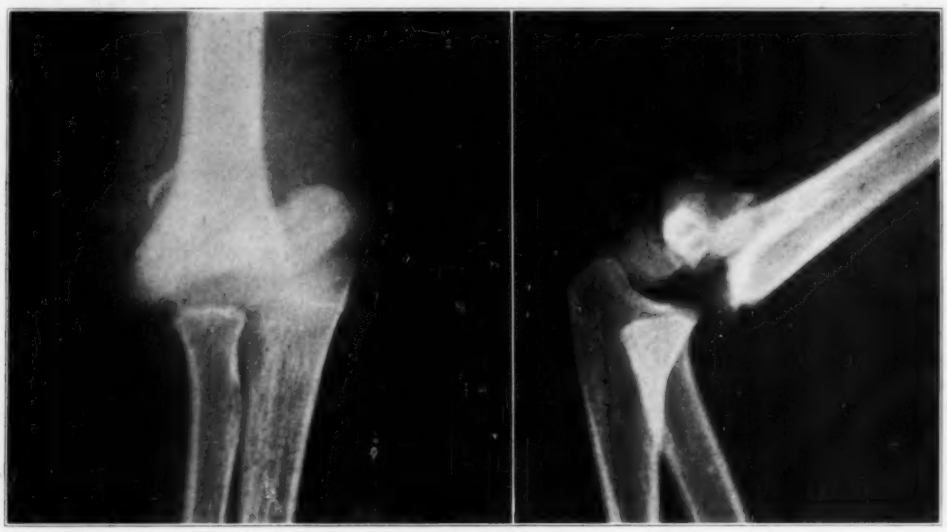

FIG. 2-A

Supracondylar fracture in a child of seven with fracture line extending into the epiphyseal plate and with disturbance of the articular surfaces of the joint.

FIG. 2-B

Poor reduction. Fracture is healing with disturbance of articular surfaces.

FIG. 2-C

Six years later, lateral views, when compared with those of normal arm (at right), show marked growth disturbances combined with traumatic arthritis. Arm now extends to 135 degrees and flexes to 45 degrees. Deformity is becoming progressively worse.

within the synovial capsule. The medial condyle fuses with a spur of bone that descends from the diaphysis and separates the condyle from the lower epiphysis proper.

Efforts have been made to produce fractures of the medial and lateral condyles and the capitellum experimentally, in order to determine the exact mechanism involved. Kini, working with cadavera, found that in fractures of the lateral condyle located beneath the attachments of the extensor carpi radialis longus and brevis, the condylar fragment was tilted outward and upward with the arm in supination. On pronation, the fragments came together. When the fragments were avulsed by the extensors, the displacement was more exaggerated, but rotation did not take place until the capsule was torn. Chamberlin points out that the normal anatomy of children differs from that of adults in that the cylindrical shaft of the humerus broadens out and thins as it reaches the elbow. The

FIG. 3-A

FIG. 3-B

Fig. 3-A: Supracondylar fracture two years after initial injury, showing posterior displacement of fragment with good general alignment.

Fig. 3-B: Four years later, fractured bone is completely remodeled. Full range of motion in elbow.

FIG. 4

Supracondylar fracture with medial displacement. Fracture line extends into the epiphyseal plate. Fracture healed with cubitus varus deformity. Full range of motion is present seven years after original injury. (This is an example of good function with a deformity present.)

ventral portion of the lower end has a hollow depression, the coronoid fossa; dorsally, a similar depression is present for the olecranon. In some instances, there is a complete bony defect in the lower shaft of the humerus at the site of these depressions; the cancellous bone makes these regions less resistant to fractures.

A series of 176 fractures of the lower end of the humerus in children was reviewed, and eighty-eight of these were followed long enough to draw some general conclusions with regard to treatment and complications. Of this latter group, fifty-five were in boys and thirty-three were in girls. The ages of the patients ranged from one to twelve years; the average age was seven. There were fifty-three supracondylar fractures, thirty-three lateral condylar fractures, one medial epicondylar fracture, and one epiphyseal separation of the capitellum.

In the present series of supracondylar fractures, end-result studies were obtained on fifty-three patients. Of these, fifty-one were treated by the conventional methods of closed reduction,—manipulation followed by immobilization in acute flexion for from two to six weeks. Traction was employed in those cases in which manipulation was unsuccessful. Of the total number, seventeen patients either had had unsuccessful manipulations or were first seen several weeks after the initial injury. These were treated by traction for periods varying from a few days to three weeks. Two of this number had early circulatory embarrassment, and the fractures were allowed to heal with the arms in optimal position for adequate circulation. One child, whose arm had been in skeletal traction for three weeks in another hospital, was admitted with osteomyelitis of the ulna. The fracture was healing in malposition with considerable callus, and no attempt was made to manipulate the fragments. In one patient a typical Volkmann's contracture and an associated ulnar palsy developed following manipulation of the fragments. The elbow function returned to normal a short time after the fracture. The forearm and hand are slowly regaining function after six years of treatment.

Eight of the supracondylar fractures were followed by cubitus varus and three had cubitus valgus deformities. In one case of severe cubitus valgus, there was an associated late ulnar-nerve palsy.

Of the total number of supracondylar fractures, thirteen, or 25 per cent., had poor

functional results. A static cubitus valgus or cubitus varus deformity with full range of motion was not classified as a bad result. The follow-up period in this group was considered adequate to allow general conclusions, although not strictly representative of a consecutive number of fractures.

Reduction of the supracondylar fractures at the time was considered good in twenty of the total number of patients. General alignment and not anatomical apposition was used as the criterion. A reduction with rotation or forward or backward tilt, which would change the range of articulation, was considered unsatisfactory. Reductions with slight lateral or medial displacements, but without rotation of the fragments, were considered adequate.

Two of the total number of these fractures were treated by open reduction. Both of

FIG. 5-A

Supracondylar fracture with lateral displacement of fragments. Fracture was treated by traction for three weeks. Good general alignment was preserved.

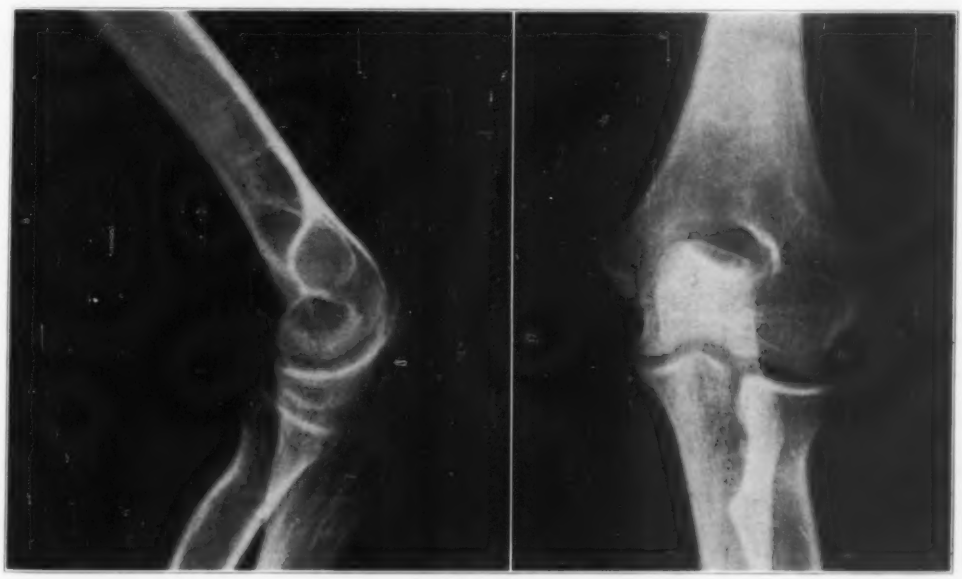

FIG. 5-B

Seven years later elbow is normal.

FIG. 6

Supracondylar fracture two years after injury. Three manipulations were required to restore anatomical position. Avascular necrosis of the trochlea is now present.

these were comminuted fractures, in which one or more of the fracture lines were through the lateral condylar region, and the condyle was displaced and rotated. Good results followed nail fixation.

One badly comminuted fracture, in which both condyles were displaced, was treated by traction for three weeks, with good results.

The poor results in this series can be grouped in two classes: (1) those due to poor

Fig. 7

Fracture seven years after original injury, showing irregularity of the joint space due to flattening of the articular surfaces. (Normal elbow at right.)

reductions, and (2) those due to fractures that had extended into the condyles and through the epiphyseal centers.

It is generally considered that, if a supracondylar fracture is reasonably well reduced, there will be little, if any, limitation of movement, and eventually the growing bone will become remodeled to offset any displacement (Figs. 3-A and 3-B). From observations of this group of fractures, this statement is true, with reservations. If the fracture is well above the articular surface and the joint is undisturbed, these fractures will heal with full elbow function. However, if there is forward or backward tilt or rotation of the fragments, the articulating surfaces are deranged, and flexion and extension are limited to a corresponding degree. If the tilt is forward, the olecranon cannot complete its range of motion, and extension will be limited. If the tilt is backward, the range of flexion will be limited. Rotation limits both flexion and extension and adds the strain of antagonistic muscle pull on the articulating surfaces. If the fragments are displaced laterally or medially, a cubitus varus or cubitus valgus deformity may follow, but this is not always disabling. Considerable displacement is allowable, if the general alignment in both planes is satisfactory (Figs. 4, 5-A, and 5-B).

FIG. 8-A

The necessity for accurate anatomical

FIG. 8-B

Fig. 8-A: Lateral condylar fracture with rotation and displacement following inaccurate open reduction and nailing one month after original injury.

Fig. 8-B: Two years after original injury, showing progressive growth disturbance and increasing valgus deformity. The range of motion is limited to 145 degrees of extension and 55 degrees of flexion.

TABLE I

FRACTURES OF THE LATERAL CONDYLES

Complications in Group of Thirty-three Fractures

Complications	No. of Cases
Growth disturbance	8
Non-union	4
Fracture of half of capitellum	2
Ulnar palsy	2
Radial palsy	1
Avascular necrosis of capitellum	1

reduction decreases as the distance from the articular surfaces and the growth centers increases. The remarkable power of growing bone to remodel itself has been apparent in a number of patients with displacement of fragments. If the fracture line, or part of it, extends into the epiphyses, more serious complications supervene, and progressive growth disturbances in the form of early fusion, overgrowth, or avascular necrosis may develop. The fracture may heal and function may return to normal, only to have deformities develop years afterward.

Avascular necrosis of the trochlea developed in four patients within a period of from two to seven years (Fig. 6). In two instances, it was associated with narrowing of the joint space and thinning of the articular cartilage (Fig. 7). In one patient, a capsulotomy was performed seven years after the initial injury, because of marked limitation of extension. This resulted in only a 35-degree increase in the range of extension of the arm. This failure was due to flattening of the trochlea.

Thirty-three lateral condylar fractures were observed in this series. Twelve were treated by manipulation and immobilization, with poor results in 50 per cent., a truly

FIG. 9-A

FIG. 9-B

Fig. 9-A: Fracture of the lateral condyle with fracture of half of the capitellum. Anteroposterior view.

Fig. 9-B: Lateral view, showing fracture line extending through the capitellum.

impressive number, since this represents the general run of fractures of the lateral condyle, and the resulting deformities are more progressive and disabling than the deformities due to supracondylar fractures.

Seventeen of these fractures were treated by open reduction and nailing. Poor results occurred in three of these (Fig. 8-A). One fracture was immobilized for one month before operation, because of excessive swelling and cutaneous blisters. The fracture of the condyle was not accurately reduced and subsequent growth disturbances developed. Another patient had a fair reduction, regaining full function of the elbow in six months, and then gradually limitation of movement with crepitation developed. One year later, roentgenograms showed avascular necrosis of the capitellum (Fig. 10-B). In addition to the fracture of the lateral condyle, there was also a fracture line through half of the capitellum, which had escaped earlier recognition (Figs. 9-A and 9-B). There was one other patient with a fracture through the lateral half of the capitellum. This patient was followed only four months and had no circulatory changes at that time.

Four patients of the series with lateral condylar fractures received no treatment, and non-union was present in all. The condyles were displaced and rotated, but were

FIG. 10-A

Open reduction with fragments not accurately replaced.

FIG. 10-B

Avascular necrosis of the capitellum and increasing joint disability one year after open reduction and nailing of fracture.

normal in size and displayed no evidence of circulatory disturbance. Two of these patients were followed over a period of twenty years; and, although there was limitation of movement, the lateral stability of the arm was preserved.

A transitory radial palsy developed in one patient following the injury of the elbow; but this disappeared a few weeks after open reduction had been performed.

In two patients of the untreated group, ulnar palsy developed. In both patients it was associated with severe valgus deformity. In four of those treated by closed reduction cubitus varus deformities developed.

Avascular necrosis of the epiphyses of the elbow region is a subject that has received but little recognition. Watson-Jones presents an excellent illustration of this condition in a lateral condyle. No mention of avascular necrosis involving the trochlea could be found.

Phemister reported a six-month-old fracture of the capitellum, in which roentgenograms showed a displaced and rotated fragment that cast shadows of varying density. At operation, the cartilaginous fragment was loosely adherent to the synovial lining, and its base was united to the bone by the underlying cortex. The specimen was found to consist of cartilage which showed very little change. The bone was extremely porous and filled with fatty marrow. Microscopic sections showed that only small parts of trabecular bone remained. This trabecular bone was necrotic, and there was a fibrous invasion of its marrow spaces. This invasion extended to the cartilage, and creeping substitution was present at its periphery. A similar fracture with slight displacement, occurring in a child, resulted in union in ten months.

In children, fractures of the lower end of the humerus which extend through the capitellum or through the trochlea (which is more of an apophysis than an epiphysis) separate the cartilage from its blood supply in the surrounding bone. If a portion of the lateral condyle is attached, the total blood supply lies in the soft tissue attached to this fragment. If, in the course of operative reduction, the soft tissues are removed, the whole fragment will undergo avascular necrosis. Every effort should be made to restore the fragment accurately, without trauma to the soft tissues.

There was one case of fracture of the medial epicondyle associated with a fracture of the olecranon. This fracture was first seen nine years after the original injury. The epiphysis had been avulsed and displaced downward into the joint, with marked disturbance of the medial condyle and non-union of the medial epicondyle. Flexion and extension were limited by 20 degrees. Undoubtedly open reduction would have been the method of choice in treating this fracture. This may not be true of fractures of the medial epicondyle, which do not include a part of the medial condyle. An excision of the medial epicondyle, rather than an open reduction, is the best procedure in such a case, for its removal does not greatly influence the development of the lower end of the humerus.

SUMMARY

Contrary to prevailing opinion, supracondylar fractures can produce serious growth disturbances if the fracture lines extend into the epiphyseal centers. Cubitus varus and cubitus valgus are not considered serious disabilities, if flexion and extension are complete. However, if the deformity is progressive and is caused by disturbances in the growth centers, disabilities and limitation of motion may occur years after the initial injury.

A satisfactory reduction is one in which the alignment in both planes is good. An anterior or posterior displacement of the fragments, in which the articular surfaces are displaced to a corresponding degree, will produce permanent limitations of flexion and extension. Lateral displacement above the epiphyses will produce valgus and varus deformities, but a good functional elbow may still result.

Supracondylar fractures in which the fracture line, or part of it, extends into the epiphyses may produce growth disturbances similar to those which result from fractures of

the lateral and medial condyles. If the fragment is intra-articular and not attached to overlying bone and soft tissue, it will undergo avascular necrosis. Supracondylar fractures of this type should have an accurate anatomical reduction; and, if the fragments are displaced and rotated, an open reduction is probably the best method of obtaining accurate alignment.

A series of lateral condylar fractures, in which there were poor results in 50 per cent. of the cases treated by closed reduction, speaks for the ineffectiveness of this method. Early open reduction with minimal trauma to soft tissues will give the best results. Avascular necrosis of the capitellum will occur if the fracture line separates the epiphysis from the overlying bone and soft tissues. Fractures of half of the capitellum occurred in two patients with lateral condylar fractures. One had poor apposition by open reduction, and avascular necrosis occurred in one year. In the other, the separation was not complete, the position was good, and healing was uneventful.

Avascular necrosis of the trochlea may occur later, despite a good reduction of a supracondylar fracture. It can cause stiffness at the joint, due to thinning of the cartilage and distortion of the articular surface of the humerus.

Delayed ulnar palsy may cause progressive growth disturbances, and was present in two cases of severe cubitus valgus deformity.

Fracture of the medial epicondyle will not cause a serious disability unless the fragment enters the joint cavity. Non-union is difficult to avoid in closed reduction.

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DISCUSSION

Dr. Edwin W. Ryerson, Chicago, Illinois: This is a very important paper. I had no idea there was such a high percentage of bad results in elbow fractures in children. Dr. Wilson finds that about 50 per cent. in the cases that he has seen have been poor; that is appalling. Though I have always been an advocate of not doing open reductions on fractures, if a good result is possible without operation, I shall certainly change my viewpoint after seeing this demonstration. It is evidently necessary to repair by operation the malposition in many of these fractures. As I looked at the roentgenograms, it seemed to me that a large proportion of these fractures could have been adequately reduced and successful results could have been obtained by the use of a hanging cast; and yet a hanging cast is not so successful in giving traction to a small child's elbow, because small children are not standing up all the time, and when they lie down, the hanging cast does not produce any traction. I think many more such patients will have to be operated upon. I have been much impressed with the use of stainless-steel wires which are threaded into the proper position and are cut off flush with the bone. This has been done for years by Compere and Phemister and many of their men with good results. Even though we have penicillin and the sulfonamides, there will be some infections if we leave wires sticking through the skin.

Dr. T. Campbell Thompson, New York, N. Y.: This presentation is most appropriate as these fractures have generally been treated much too casually. It is evident from Dr. McDonnell and Dr. Wilson's study that such fractures require skillful treatment. It is our belief that all patients with elbow fractures, except possibly those of the radial head, should be admitted to the hospital for a short period to check the reduction and avoid complications. One case of Volkmann's contracture is just one too many. I should be interested to hear how the one case in this series happened to occur. No credit can be claimed for a good reduction of an elbow fracture if the irreversible reaction of fibrosis of the structures in the forearm and loss of function in the hand has occurred.

The use of traction, as described by Dr. Dunlop, as a method of primary treatment in fractures through the condyles and close to the elbow joint should always be considered a method of primary treatment rather than one used only when manipulation fails.

In regard to fractures of the external condyle and capitellum, it is evident that early open reduction is the method of choice. Some surgeons maintain that they can reduce these fractures by manipulation, but many of us are not so dexterous. An early open reduction is indicated in these cases just as much as in fractures of the patella or olecranon where muscle pull is bound to displace a fragment. Certainly the fracture should be accurately reduced and the fragment firmly fixed, leaving the soft tissues attached to it in order to preserve its circulation.

I should like to show the roentgenograms in a complicated case where such a procedure was not possible. In the ten-year follow-up it was interesting to see what has happened to the fragment, which included the entire capitellum, after it had been completely removed and replaced. For a time I thought this epiphysis was actually growing, but now I am not sure. I should like to ask Dr. Wilson what procedure he would suggest in such a case.

On June 23, 1937, this boy fell on his outstretched arm and sustained a fracture of the external condyle with medial dislocation of the forearm and humerus. The fracture was reduced elsewhere and the arm was immobilized in plaster for four and one-half weeks. Seven weeks after injury, August 12, 1937, the boy was admitted to the hospital with complete disarrangement of the bony landmarks about the elbow and motion of 80 to 105 degrees. Pronation and supination were limited, and there were ulnar-nerve symptoms. X-rays showed medial displacement of the radius and ulna and rotation of the external condyle. On August 14, through a posterior arthroplasty incision, the soft tissues were stretched freely and the dislocation was reduced. The external condyle had to be entirely separated from the extensor muscles in order to replace it. It was held in position with a bone peg. The postoperative course was uneventful. Three months postoperatively, movement was improving rapidly (45 to 125 degrees) and pronation and supination were complete. At the end of three years the flexion was perfect. Extension was limited to from 20 to 145 degrees. Pronation and supination were normal. X-rays taken on January 14, 1947, ten years after the operation, showed a 15-degree increase in the carrying angle; motion of from 25 to 150 degrees was present.

DR. J. S. SPEED, MEMPHIS, TENNESSEE: I think this is too important a subject to pass over without some positive remarks being made with regard to it. Dr. Wilson's paper clearly illustrates the fact that open reduction is the only way to treat fractures of the lateral condyle. Poor results in 50 per cent. of these cases illustrate the necessity for doing something immediately when these fractures occur. We reviewed our cases many years ago and found that, in the vast majority of them, we could not reduce these fractures by closed manipulation. If you want to get the best results in a large number of cases do an immediate open operation.

Dr. Thompson's case illustrates the point that the time to do the reduction is immediately. After three or four weeks the opportunity to restore a normal elbow has been lost, because the blood supply to these fragments cannot be preserved if the elbow is operated upon late. To mobilize the fragment you have to take off the soft tissues,—thereby interfering with the blood supply. I would like to make a plea for immediate reduction with internal fixation in all fractures of the capitellum in children.

DR. JOHN C. WILSON (closing): I wish to thank the gentlemen for their interesting discussion. The late circulatory changes which occurred in the fracture fragments proved to be the most fascinating part of this study. These are associated with rather bizarre growth disturbances. It is disconcerting to reduce a fracture, tell the parents everything will go well, and then have the patient return in a few years with a severe deformity. Sufficient attention has not been directed to the fact that changes in circulation do occur, and, if severe, will cause changes in the articular surfaces which may result in limited motion of the joint.

It is believed that excision of the capitellum is not a good procedure. Even though it does not unite, it acts as a buttress to prevent deformity of the elbow. This has been exemplified very well in the slides shown by Dr. Thompson, and it occurred in two instances in the series of patients studied.

THE CINEPLASTIC METHOD IN UPPER-EXTREMITY AMPUTATIONS*

BY RUFUS H. ALLDREDGE, M.D., NEW ORLEANS, LOUISIANA

Recent renewal of interest in amputations and artificial limbs has resulted in the accumulation of additional information on the cineplastic amputation and prosthesis, which, if properly considered, may eventually increase the usefulness of this method. This information includes recent developments in the surgery of the method, as well as more knowledge of the shortcomings of the old type of prosthesis and principles which newer prostheses should incorporate.

Sauerbruch's cineplastic method is the only one which has survived, and it is well known everywhere, having been in use for over thirty years. The purpose of this paper is to review some of the important principles of the surgery and prosthesis, learned in this country and in Germany during the past year. The work in Germany was observed by the Army Surgeon General's European Commission on Amputations and Prostheses**, early in 1946. Since that time, considerable work has been done on the prosthesis by the Committee on Artificial Limbs of the National Research Council.

The Cineplastic Method in Germany

The greater part of the cineplastic work in Germany has been done in two centers, each with complete shop facilities for prostheses, located in the hospitals in which the surgery is done. F. Sauerbruch himself was actively in charge of the work at *Charite Krankenhaus* in Berlin, and Prof. Max Lebsche was the surgeon in charge of this work at several hospitals in Munich, including the *Chirurgische Klinik* of the University of Munich. Several thousand cineplastic operations were done on World War II amputees in these two centers. Patients were usually given a choice of the cineplastic method, the Krukenberg operation, or the conventional methods not requiring special operative procedures. No particular method was urged upon any patient. The Krukenberg method was commonly used on below-the-elbow amputations by many surgeons, particularly for bilateral amputees. One reason for this was that, with the Krukenberg method, a prosthesis was not required. For some bilateral amputees, the cineplastic method was used on one side and the Krukenberg method on the other. Many amputees in cineplastic centers, where prostheses were available for the cineplastic amputation, chose the Krukenberg method. Many others, particularly unilateral amputees under the same circumstances, preferred the conventional methods which usually included the use of the work arm.

In Berlin, the cineplastic method was used exclusively at *Charite Krankenhaus* by Sauerbruch. Those desiring the Krukenberg method were cared for at the *Oscar Helene Heim;* there over five hundred Krukenberg operations had been done, the majority on bilateral cases, and over fifty of these on blind bilateral amputees. In Munich, Lebsche used all methods, according to the needs and desires of the individual patients.

The results of cineplastic surgery in the patients seen were generally excellent. Complications were rare, and the muscle motors had good excursion and strength. Sauerbruch had continued to use the standard technique, but Lebsche had introduced a modification which seemed to give improved results without unduly complicating the procedure. In addition to the use of the usual Sauerbruch technique, he had practised liberation or division of the distal insertion or attachment of the muscle through which the tunnel was placed. This modification had been used by Lebsche on over five hundred cases during the

*Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1947.

** Members: Leonard T. Peterson, M.D., Paul E. Klopsteg, Ph.D., Rufus H. Alldredge, M.D., E. M. Wagner, and R. G. F. Lewis.

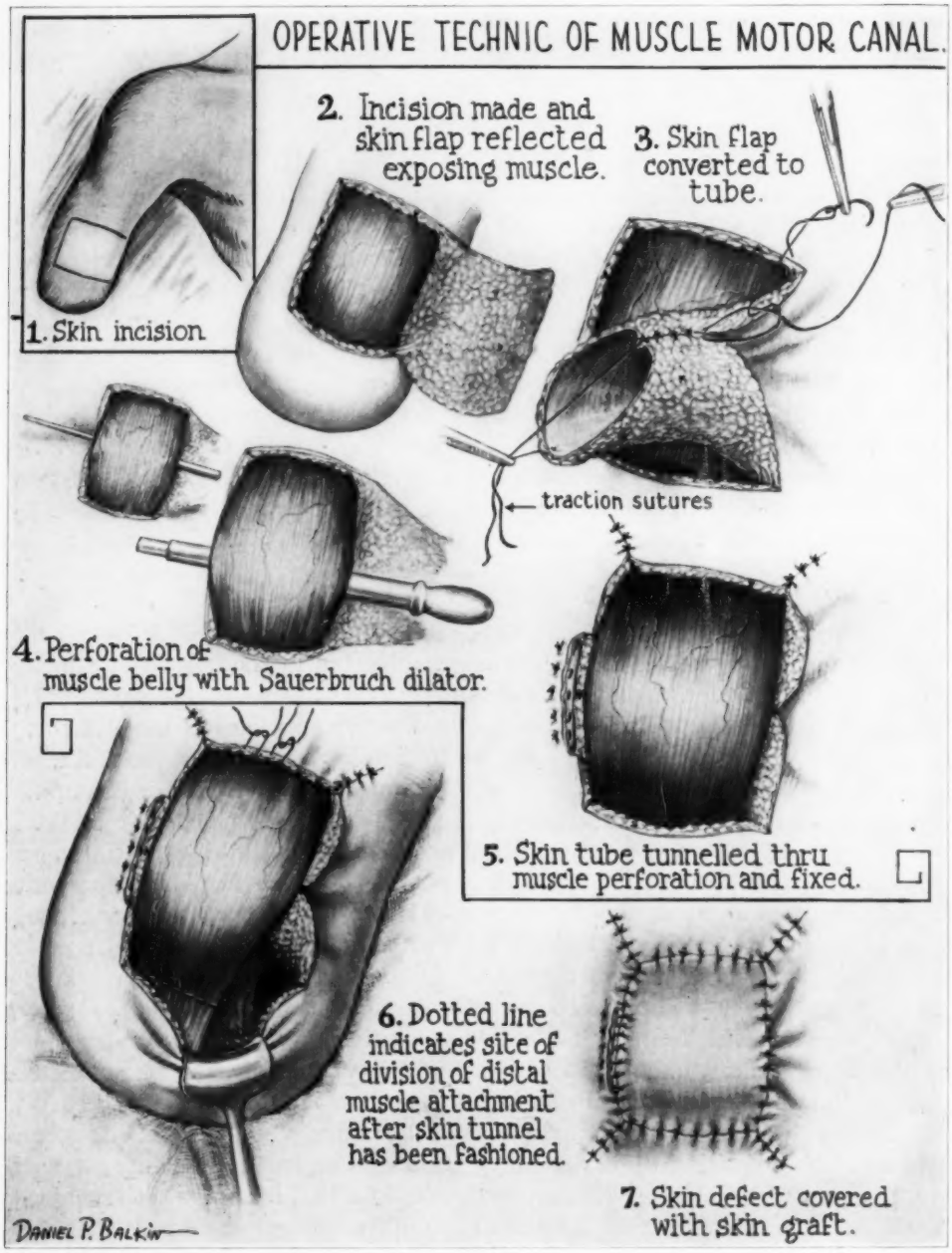
OPERATIVE TECHNIC OF MUSCLE MOTOR CANAL.
1. Skin incision.
2. Incision made and skin flap reflected exposing muscle.
3. Skin flap converted to tube.
traction sutures
4. Perforation of muscle belly with Sauerbruch dilator.
5. Skin tube tunnelled thru muscle perforation and fixed.
6. Dotted line indicates site of division of distal muscle attachment after skin tunnel has been fashioned.
7. Skin defect covered with skin graft.
DANIEL P. BALKIN

FIG. 1

Surgical technique of cineplastic muscle-motor construction.

three-year period from 1943 to 1946. Many of the results were seen in all postoperative stages, and a definite impression was gained that the muscle motors had more strength and excursion, and that they could be better controlled by the patient, than any seen elsewhere. A number of patients operated upon elsewhere by the standard technique were seen in Munich before and after further surgery was carried out by Lebsche to liberate the distal muscle attachments. These patients were definitely improved by this additional procedure.

The German cineplastic prosthesis was essentially the same as that originally developed by Sauerbruch and his associates. It lacked many desirable cosmetic, functional, and mechanical features.

Principles of the Cineplastic Method

The cineplastic method of Sauerbruch has been described in this country in numerous articles by Kessler and in a monograph by Nissen and Bergmann. It is not necessary to repeat much of what has been said in these excellent writings; those who are interested are referred to them for further details.

The distal ends of the muscles of the stump are canalized by the use of skin tubes. Usually two are employed, one through the flexor muscles and one through the extensors. After sound surgical healing has taken place, a rod passed through the skin-lined muscle canal or tube is activated by contraction of the muscle. The rod is connected to the prosthesis from each end; and the flexor muscle motor thus acts upon the artificial hand to close it, while the extensor performs the opposite function.

Preoperative Care

The preoperative care of the patient consists chiefly in the use of exercises to develop fully the muscles of the remaining arm stump and those which act upon it. All of the muscles are thoroughly exercised, and the patient is taught to develop active use of the muscles through which the muscle tunnels will be placed. Patients who have actively used the muscles of the stump in their daily activities may not need any special exercises, but a period of from one to six weeks may be required for proper muscle development.

Principles and Technique of Cineplastic Surgery

Cineplastic operations in Germany are performed with the use of local infiltration anaesthesia exclusively. No tourniquet is used. This enables the patient to cooperate fully with the surgeon in properly carrying out the operation. After the limb has been adequately prepared, draped, and anaesthetized, the patient is instructed to actively contract the muscle through which the skin tube is to be placed. This materially assists the surgeon in locating exactly the most desirable site of incision for the skin flap from which the tube is to be constructed. The skin flap is planned in such a way that, when it has been converted into a tube, the tube will lie at a right angle to the fibers of the muscle through which it is to pass. It should be at the level of the most distal part of the muscle belly which can be used for perforation. The skin flap should be designed so that the tube will be as wide and as short as possible. The size of the skin flap varies at each level, being smaller below the elbow than above.

The incisions for the flap are made on three sides of a square or rectangle, so that a square or rectangular flap is made with its base left attached. The two parallel incisions are made transverse to the axis of the muscle fibers to be perforated. All three incisions extend through the subcutaneous tissue and fat, and the deep layer of fascia. All of these structures are then undercut and reflected as a flap to the base, which is carefully left intact.

The flap is planned so that its base is toward the side of the arm having the best circulation. Below the elbow the base is toward the radial side, and above the elbow it is toward the medial side. For the pectoral flap, the base is toward the axilla. When two muscle motors are to be used, they may be constructed at the same operation and the bases of both flaps may be toward the same side, even if they are at the same level of the stump. The bases of skin flaps may be planned in the opposite directions if scars are present which might interfere with circulation to the flaps.

The elevated skin flap is suspended and held taut by the use of two stay sutures, while the surgeon sutures the edges of the flap together to form a tube, using interrupted extracutaneous, non-absorbable sutures (Fig. 1). The suture line is started at the free end of the tube, and is continued toward the base of the flap until the skin edges will no longer come together. The underlying muscle belly is then held by the operator with the thumb

and finger of the left hand, while the muscle is perforated with the muscle dilator (Fig. 1). The muscle perforation must be larger than the skin tube, but under no circumstances should the perforator be pushed far enough to rupture the muscle. The perforation is never made through tendons, and it is important that it extend through the muscle and not between muscles. The muscle is perforated in such a way that one-third to one-half of the muscle belly is left over the superficial surface of the tunnel. The skin tube is pulled through the muscle tunnel by the use of the stay sutures originally applied. The tube is then rotated

FIG. 2-A

Photograph of bilateral forearm amputee. Bilateral forearm flexor and extensor muscle motors have removable ivory pegs through tunnels.

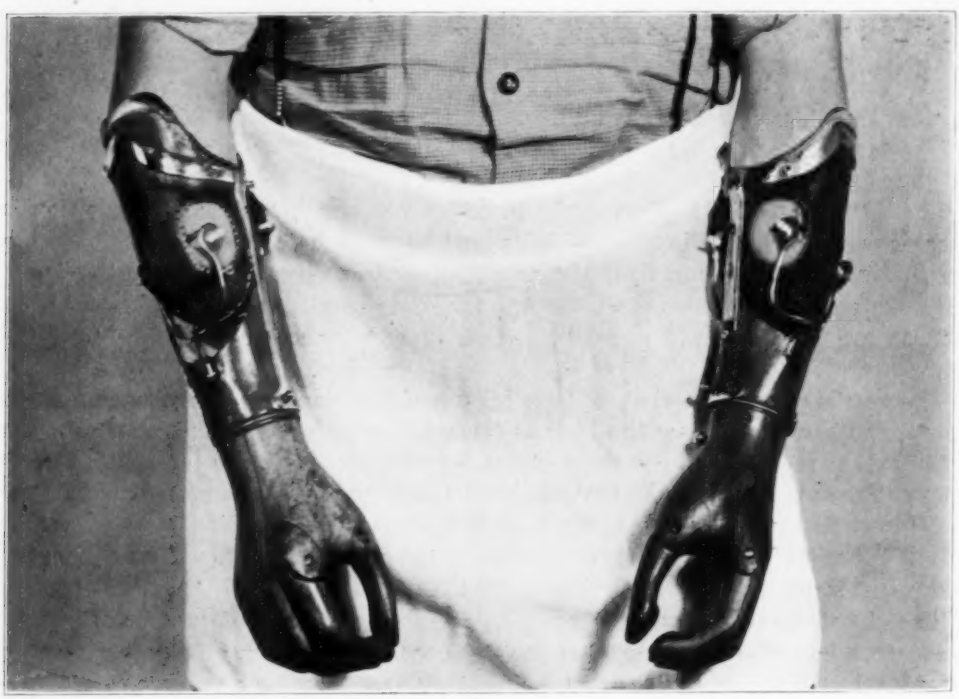

FIG. 2-B

After application of prostheses. (Both surgery and prostheses were German.)

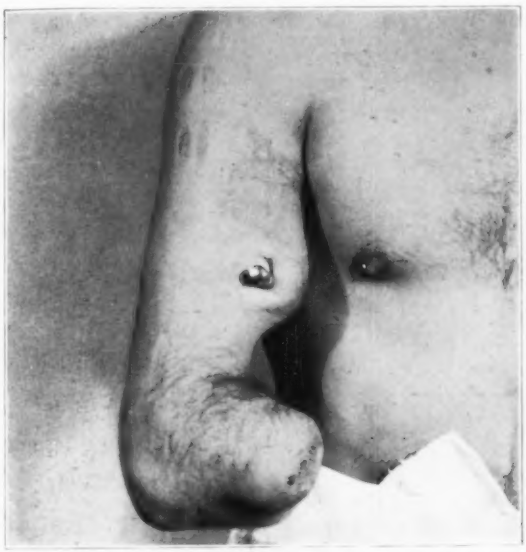

FIG. 3-A

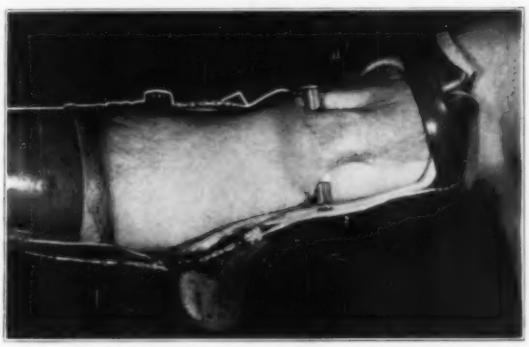

FIG. 3-B

FIG. 3-C

Fig. 3-A: Biceps muscle motor for short below-the-elbow amputation.
Fig. 3-B: Front view, showing attachment of prosthesis to ivory rod.
Fig. 3-C: Prosthesis is attached. (The surgery and prosthesis are German.)

proximally 90 degrees at the distal end, so that the suture line is placed on the proximal side of the tube. This removes the suture line from the pressure of the rod when the prosthesis is used. The end of the skin tube is then sutured to the center of the nearby free edge of the skin. If the tube is found to be longer than necessary, it may be shortened by removing some sutures and spreading out the open end of the tube over the underlying muscle. This also helps to cover the denuded area.

This is the point at which the distal muscle attachment is liberated when Lebsche's technique is used. The muscles can be freed up or the tendons can be divided by undercutting and retracting the distal free skin edge. The remaining open wound is closed as much as possible by skin sutures at the sides and corners. The free skin edges are sutured subcutaneously, directly to the exposed muscle. The remaining area is covered by a skin graft, 0.025 to 0.028 of an inch thick. After the graft has been sutured in place, a pressure dressing is applied without the use of a splint. The skin tube is left empty until wound healing has taken place.

In the construction of the biceps muscle motor, where the full length of the biceps is present, it is important to plan the flap so that the tube formed from it will be at a higher level than the distal end of the biceps muscle belly, while the distal tendon is attached. The muscle is perforated, as usual, through the distal end of the muscle fibers,

which is considerably distal to the level of the skin tube. The elbow is then flexed to bring the biceps perforation proximally to the level of the skin tube, so that the tube can easily be placed through the muscle opening without undue tension or stretch on the tube. The biceps tendon and the lacertus fibrosus are divided, after which the level of the muscle perforation permanently moves up to the skin-tube level, as a result of the muscle shortening which takes place when its insertion is liberated. The elbow can then be extended without disturbing the level of the muscle tunnel or the skin tube. The patient has independent action of the elbow and of the biceps motor. After such a procedure, elbow flexion by the brachialis is apparently as strong as it was with the biceps insertion intact.

In construction of the pectoral motor, a separate incision is made over the anterior axillary fold to the insertion of the muscle. This incision is usually four or five inches (ten or twelve centimeters) in length and starts directly at the center of the free edge of skin, from where the skin flap has been raised. After the insertion of the muscle has been released, the incision is closed in the usual way.

Postoperative Care

The dressing is taken off in ten or twelve days, at which time the sutures are removed. A rod, similar to that which is used with the prosthesis, is inserted into the muscle tube;

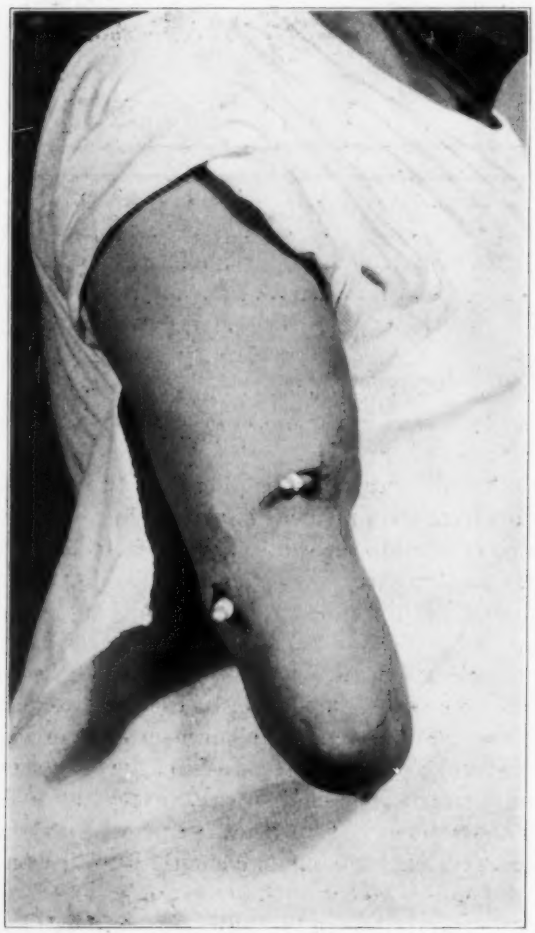

FIG. 4-A

FIG. 4-B

Fig. 4-A: Biceps and triceps muscle motors for amputation through elbow. Cineplastic surgery was performed in 1919 in Germany.

Fig. 4-B: German prosthesis is attached. This patient has used a prosthesis continuously since 1919.

FIG. 5

FIG. 6

Fig. 5: Shows harness arrangement for above-the-elbow prosthesis. The posterior extension cord of the harness flexes the elbow, and the anterior extension cord supinates the hand of the prosthesis.
Fig. 6: The pectoral-muscle motor and prosthesis. (Surgery and prosthesis are German.)

and, with the muscle stretched, the patient is instructed to contract the muscle. This procedure is repeated daily until complete healing takes place; thereafter, the patient carries out his own exercises. It is necessary for the exercises to be performed against a pull or stretch on the muscle through the rod. This can be done by the patient or some other individual pulling on the rod enough to stretch the muscle to its full length. Sometimes a weight is suspended from the rod which passes through the muscle tunnel, and the patient exercises the muscle by standing and pulling the weight against gravity. The weight may be increased daily as the power of the muscle increases. These exercises against a pull on the muscle to stretch it are especially important in cases in which the distal muscle attachment has been liberated. The exercises are continued until the prosthesis is fitted. The muscle tubes are cleansed daily with soap and water and alcohol. Powder is not used. A minute sleeve of cotton fabric, similar to stockinette, may be used over the rods to protect the skin tunnels.

Sites of Muscle Motors

The judgment necessary in deciding upon the sites at which muscle motors are to be placed for amputation at the various levels can best be developed from a thorough understanding of the various possible types of prostheses, as well as all other aspects of the method. Faulty placement of the motors may result in complete failure, even though surgery is otherwise carried out properly. The longer the muscle through which the tube is passed, generally the greater will be the excursion of the muscle motor. At best, a muscle motor usually cannot have an excursion greater than half the length of the muscle belly through which it passes. Excursion of the muscle motor is, therefore, determined by the length of the muscle. Excursion is more important than strength. The strength of muscle, unlike excursion, is not related to length, but is in direct proportion to the thickness or diameter of the muscle. The strength of a muscle can be altered by exercises which increase the diameter; but the excursion cannot easily be altered so favorably, since the

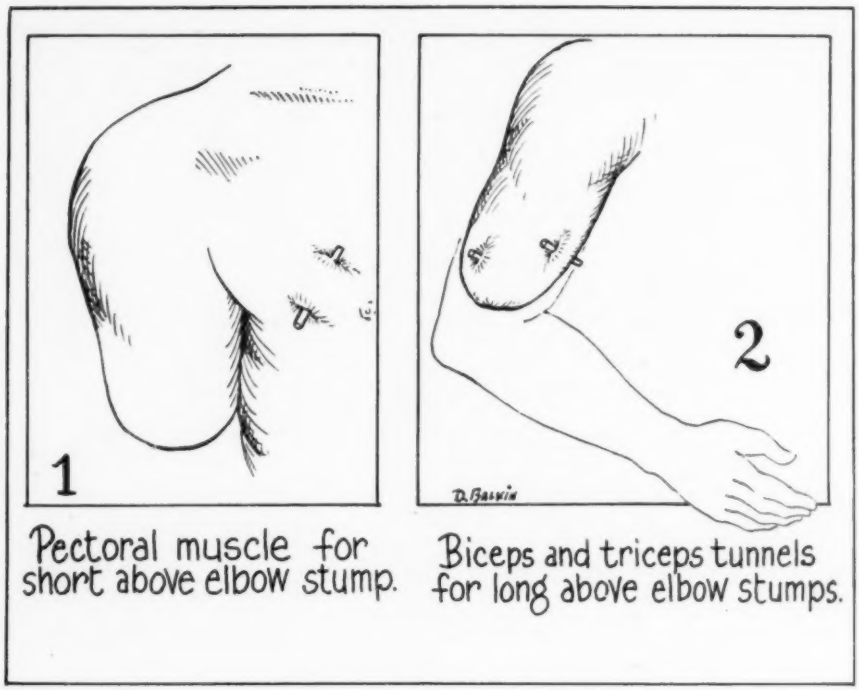

FIG. 7

Sites for muscle motors.

length of the muscle cannot be increased. This means that muscle motors will function better in long stumps than in short ones. Furthermore, patients with long stumps have better control of the prosthesis than those with short stumps.

Generally speaking, muscle motors should not be constructed on stumps which terminate at the level of or proximal to the juncture of the middle and upper thirds of the arm or forearm. In short forearm stumps, the biceps alone or the biceps and triceps are tunneled. When the amputation is higher than the middle third of the upper arm, the pectoral tunnel is used.

Flexor and Extensor Muscle Motors for Forearm Amputations

Usually two muscle motors are used in the forearm stump of good length,—one through the flexor muscles and one through the extensors. The muscle tunnels are placed through the most distal part of the muscle bellies, just above the musculotendinous juncture. The flexor tunnel is placed through the flexor digitorum sublimis, and the extensor tunnel through the extensor digitorum communis. It is important that the tunnels pass through the muscles and not between them.

The best length for a forearm stump is at the level of the lower and middle thirds, or slightly below this level. Amputation through the wrist does not provide a favorable site for cineplasty. The flexor motor closes the artificial hand and the extensor opens it. The prosthesis does not extend above the elbow. Passively operated rotation at the wrist may be locked at any point. There is also a lock to maintain the hand in the closed position for prolonged holding. The flexor motor has more strength and excursion than the extensor; but, since the function of opening the hand is much less important than that of closing it and grasping, this makes little difference. Forearm motors have less strength and excursion than those above the elbow; but this does not detract from the practical result, as the motors are nearer the prosthesis, and the retained elbow function makes the end result at least as good as that in cases in which above-the-elbow motors are used for

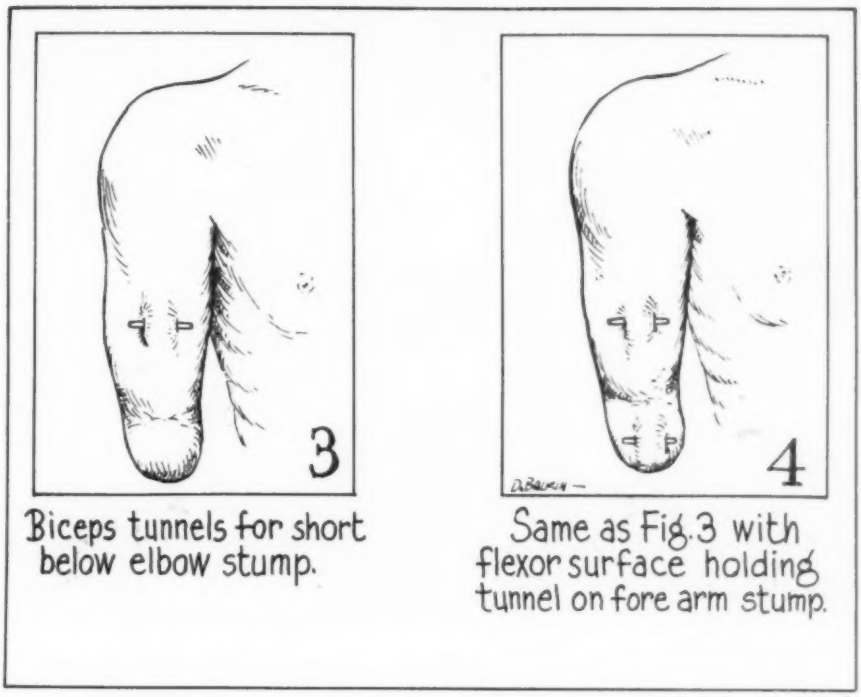

FIG. 8

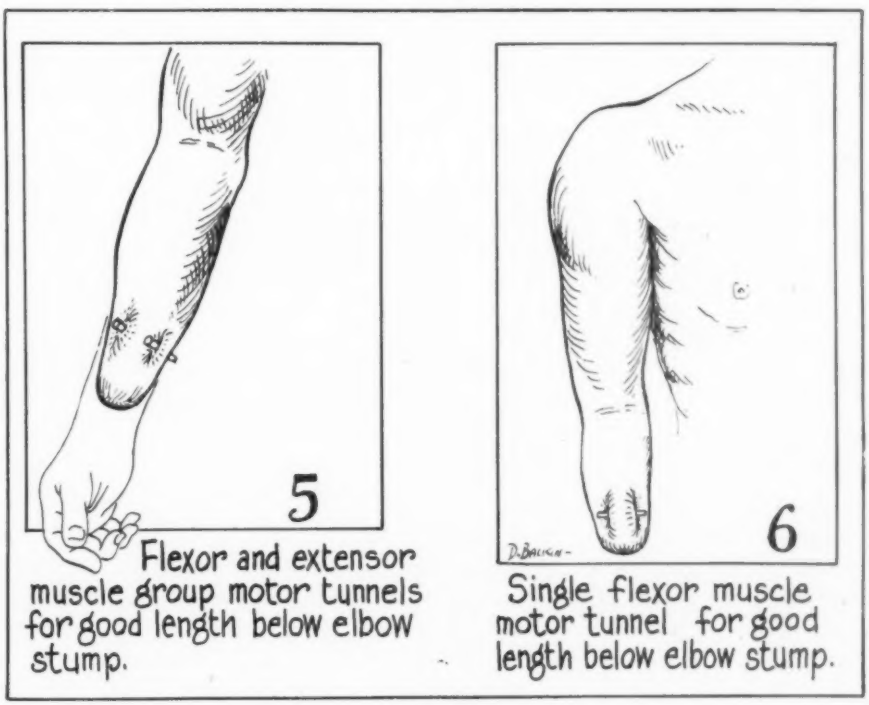
5
Flexor and extensor muscle group motor tunnels for good length below elbow stump.
6
Single flexor muscle motor tunnel for good length below elbow stump.

FIG. 9

Sites for muscle motors.

above-the-elbow amputations. Forearm motors are best used at a level which corresponds to the ends of the bellies of the muscles through which the tunnels pass, and should not be used in any forearm stump which terminates at the level of or proximal to the juncture of

FIG. 10

The Krukenberg stump in German war wounded. A prosthesis is not usually employed on this type of stump.

the middle and upper thirds of the forearm. The average excursion of the forearm flexor motor is from 1 to 2 centimeters, and that of the extensor is from 1 to 1.5 centimeters. The flexor motor is capable of pulling from fifteen to twenty-five pounds, and the extensor from ten to fifteen pounds.

Flexor Motor Alone on Forearm Stump

Although there are good theoretical reasons for using both the flexor and extensor muscle motors whenever possible, it is not always necessary to do so. The flexor motor alone may be used if the extensors cannot be utilized, or if the patient prefers only one motor. In this case, a spring in the hand performs the function of the extensor motor. A number of patients with single flexor motors of the forearm were observed in Munich; and some patients actually preferred the use of only one, declaring that they could do as much with one motor as others could do with two. With only one motor, it is necessary for a leather strap to be used above the elbow to help suspend the prosthesis; otherwise the prosthesis is the same as that used for double forearm motors.

Biceps and Triceps Motors for Amputations below the Elbow

When the forearm stump is too short for canalization, either a biceps motor alone or a biceps and a triceps motor may be used. Lebsche usually employed the biceps motor alone for short forearm stumps. The results in these cases were among the most impressive of any seen in Germany. Lebsche also used the single biceps motor in many long forearm stumps from choice, in men who had to do work that was heavier than average. The biceps muscle motor, when used for amputations below the elbow, gives the best function of all, whether it is used in conjunction with the triceps motor or alone. When the biceps motor is used alone, it acts on the prosthesis to close the thumb and fingers simultaneously; and a spring opens the hand, instead of the triceps motor. The elbow of the prosthesis is moved by the short stump, which fits into a socket; otherwise the prosthesis is the same as that for forearm flexor and extensor motors. When the triceps motor is used with the biceps, the

former serves to open the hand instead of the spring. The biceps motor has an excursion of from 5 to 7 centimeters and will pull from forty to seventy pounds of weight. The triceps has much less excursion and strength than the biceps.

FIG. 11-A

FIG. 11-B

FIG. 11-C

FIG. 11-D

A bilateral German amputee with two Krukenberg stumps. Surgery was performed six years before the photographs were taken in Berlin, in 1946. This man was the amputee instructor for all patients with Krukenberg stumps at *Oscar Helene Heim* in Berlin, where several hundred Krukenberg operations had been performed. He was completely independent with the use of his stumps.

Biceps and Triceps Muscle Motors for Amputations through and above the Elbow

These motors may be used successfully on amputations through the elbow joint, but it is necessary for the portion of the prosthesis above the elbow to be elongated by the insertion of the elbow mechanism below the end of the stump. In such a case it is necessary for the forearm part of the prosthesis to be shortened, for equalization of over-all length. The site of choice for above-the-elbow amputations is just above the condyles of the humerus. The biceps motor closes the hand and the triceps opens it. In addition, active supination of the hand at the wrist joint and active flexion of the elbow of the prosthesis are obtained by the use of a shoulder harness. A spring in the artificial hand acts against supination to return the hand to a resting position of pronation. These muscle motors should not be used on stumps which terminate at the level of or proximal to the juncture of the middle and upper thirds of the arm.

The Pectoral-Muscle Motor

The pectoral motor has the greatest excursion and strength of any motor in the upper extremity. Excursion ranges from 5 to 9 centimeters, and strength from fifty to over one hundred pounds. Unfortunately, the amputee is unable to control the function of the pectoral motor as well as that of the others, and much of its strength and excursion are lost in transmission from the motor to the prosthesis. The pectoral-muscle motor may be used alone on stumps too short for biceps and triceps motors, or in conjunction with biceps and triceps motors. Lebsche has used the pectoral motor in many cases, including some bilateral amputees, and the results have been encouraging enough to justify continuance of its use.

The Holding or Stabilizing Tunnel

In some cases, skin tunnels are constructed purely for the purpose of stabilizing the prosthesis on the arm stump, and they may or may not be passed through part of a muscle. On short below-the-elbow amputations in which the stump tends to become displaced out of the socket of the prosthesis with flexion of the elbow, a skin holding tunnel on the flexor surface of the short stump may aid materially in maintaining the stump in the socket. This type of holding tunnel usually does not pass through the muscle, as no great amount of pull is exerted upon it. Another site for the placement of a holding tunnel is the posterior surface of the above-the-elbow stump, when the pectoral motor is used to move the prosthesis. This tunnel is subject to great stress in offsetting the forward displacement of the prosthesis by the powerful pull of the pectoral motor, and is constructed in the usual way and placed through the muscle.

Muscle Physiology in Relation to Cineplastic Muscle Motors and Prostheses

There has recently been a revival of interest in the physiology of muscle in relation to the requirements of the prosthesis for cineplastic amputations. The University of California workers for the Committee on Artificial Limbs have reviewed muscle physiology and made rather extensive studies of the physiology of the muscles of cineplastic amputees in whom the insertions of the muscles had been divided. Dr. Verne T. Inman has been most interested in these studies; he and his co-workers have made interesting and valuable observations, the implications of which are clear regarding the requirements of the cineplastic prosthesis. Inman and the California workers have studied the dynamics of isolated human muscle in cineplastic amputees, to determine the characteristics of muscle which are essential in the design of a prosthesis by which the potentialities of the muscle can be realized. A definite relationship has been revealed, by studies of isometric muscle tension, between the length of the muscle and its active tension. The greater the muscle length, the greater the tension that can be developed. A study of the ability of the tunneled muscles to shorten

against increasing loads revealed a linear relationship between the load and the distance the muscle could shorten,—the greater the load, the shorter distance the muscle could move it. Attention has been called to the natural compensatory mechanisms in the body, causing the muscle to be used at its most advantageous length. The necessity for the interposition of compensating mechanisms in the prosthesis to mimic those in the body has been pointed out. What is needed, in other words, is not merely a force multiplier which goes into action when a certain amount of pull is applied. Mechanisms must be developed which will maintain the tunneled muscle at its greatest length, throughout the range of motion of the various parts of the prosthesis.

The German prosthesis and its modifications do not incorporate any of the principles suggested by these studies.

SUMMARY

Observations by the Army Surgeon General's European Commission on Amputations and Prostheses early in 1946, and the work of the Committee on Artificial Limbs since that time, have resulted in additional knowledge of the cineplastic method. The only cineplastic method still in use is that of Sauerbruch, developed in Germany during and after World War I. Little was known, until early in 1946, of the status of cineplasty in Germany or of the management of arm amputations in general in that country during and since World War II.

The cineplastic method was found to be in active use chiefly in two centers, Munich and Berlin. Cineplasty was by no means used to the exclusion of other methods, even in these two centers. Patients were usually given their choice of the three methods generally used,—the cineplastic, the Krukenberg, and the conventional methods requiring no special surgical procedures.

Prof. Max Lebsche of Munich introduced the practice of liberating the distal attachment of the canalized muscle in cineplastic operations. This modification seemed to improve the results without unduly complicating the procedure. The surgery of cineplasty was found to be highly developed. It is doubtful if the surgical aspects of the method can be improved appreciably.

The principle of the method consists in the use of two muscle motors on the arm; these are constructed by raising a flap of skin on the stump and converting it into a tube, which is placed through a hole in the muscle belly. When the muscle is contracted by the amputee, the tube is moved. A rod through the tube is connected to the prosthesis. Active contraction of the muscle thus governs the action of the prosthesis through the rod. One muscle motor is constructed on the flexor surface of the arm and the other on the extensor surface.

The selection of the sites for placement of the muscle motors is of the utmost importance. The muscles should be tunneled at the distal end of the muscle fibers. The excursion of the muscle tunnel is in direct proportion to the length of the muscle through which the tube passes. The strength of the motor is in direct proportion to the width or diameter of the muscle belly. The biceps alone or the biceps and triceps should both be canalized for short stumps below the elbow, and the pectoral motor should be used for short arm stumps above the elbow.

The preoperative and postoperative care, consisting chiefly in proper muscle exercises, is highly important. Before operation, all of the muscles are strengthened to the maximum extent, and the patient is taught selective use of those to be tunneled. Following operation, the patient is taught active use of the muscle motors, while the muscles are stretched to their full length. Strength and excursion of the motors are increased by active contraction of the muscle motor against gradually increasing resistance on a rod which passes through the tunnel.

The German prosthesis is still essentially the same as that originally developed.

It is lacking in cosmetic, mechanical, and functional qualities. It is also very delicate, and the component parts are subject to wear and frequent breakage. At present, no prosthesis is known which is essentially different or better than the German one.

Much recent work has been done on the cineplastic method by the Committee on Artificial Limbs. Fundamental research has been carried out on cineplastic amputees, with particular regard to the physiology of the muscle motors in relation to the mechanical needs of the prosthesis. Results of these studies at the University of California have already indicated a definite need for compensatory mechanisms in the prosthesis, to take the place of the natural ones which were lost when amputation was sustained. The incorporation of these and other valuable principles, worked out by the Committee on Artificial Limbs, should improve the future prosthesis appreciably. When this has been done and a better prosthesis has been made available for use in properly organized cineplastic centers, the method may well enjoy more extended use than at present.

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DISCUSSION

Dr. Paul B. Magnuson, Chicago, Illinois: As you know, Dr. Alldredge was Chief of the Amputation Service at one of the Army General Hospitals during the War and was selected by the Army and the Committee on Artificial Limbs of the National Research Council to go to Germany with certain engineers, accompanied by Colonel Peterson of the Army, to investigate the possibilities of improvement of artificial limbs. I think most of Dr. Alldredge's time there was spent in investigating the cineplastic technique. He stayed longer than the rest of the Committee, and came back after studying the possibilities of the cineplastic operation.

The cineplastic operation differs in two ways from the old Sauerbruch method: (1) The muscle is severed from its attachment; and (2) a very much larger tube is made, through which the peg is passed. Both changes seem to be important. The size of the tube is larger and, consequently, the skin lining the tube can be kept in much better condition. The larger the tube and the larger the peg, the less pressure there is on the skin with movement of the apparatus.

The Committee on Artificial Limbs has been trying to devise better prostheses for use in these cineplastic operations, and that is a mechanical problem which has up to now baffled some of our best mechanics. Dr. Inman of the University of California has gathered, in the process of this investigation, some very interesting facts on actual muscle motors. I think I heard him say that he had seen pull of 100 pounds exerted by the biceps in a straight pull. Most of the power exerted is in direct proportion to the length of travel of the muscle. You can develop the breadth of the muscle, but the amount of acceleration depends upon where the peg is placed. It seems to be necessary with most of these prostheses, if we are to get good results, to place the peg right and to choose the right muscles for giving power. Some kind of a booster mechanism will have to be made in order to get extra grip. There are certain other features which Dr. Wilson will bring out.

I have seen Dr. Alldredge do some of these operations. A patient who is willing to work before the

operation will get good results from this cineplastic amputation. We have not forced this operation on anyone. We have asked for volunteers. Some enthusiastic surgeons have done operations without having had the muscles developed previously and without knowing what sort of prosthesis the patient was going to wear. I hope this operation will not become too popular because it is easy to do. Its success will depend upon the following factors: placing the tube in the right place, the development of the muscles before the tube is placed in position, and the development of a proper prosthesis. Just now the poor prosthesis is the great handicap.

Dr. Philip D. Wilson, New York, N. Y.: I want to congratulate Dr. Alldredge on this excellent motion picture, which I think has showed both the surgery and the results in a way that has not been done before. In our enthusiasm for the cineplastic amputation as it is shown today and for the recent developments in Germany, we must not lose sight of the pioneer work that Dr. Henry Kessler did in this country. For many years he was the lone person in this country to do this operation. He went to Germany to learn the technique in the 1920's. He brought back appliances and set up his own bracemaker. This has been purely a philanthropic endeavor on his part.

We are held back by the lack of a suitable appliance. The surgery is much further developed than the prosthesis. Even today, with all the efforts of the Committee on Artificial Limbs, with considerable funds at their disposal, and with considerable scientific talent to call upon, we have been slow to produce a hand that is as good as the one the Germans have been manufacturing for some years. I do not say we are not going to find the answer, because I think we will, but it is very difficult.

The study of the physiology, made by Dr. Inman, is very interesting. I hope, if time permits, that we may hear from him. In 1918 I accompanied the late William Baer to Italy to study and report to the U. S. Army on the cineplastic amputation which was done by Putti. We had many talks with Putti and his associates and with Dr. Vangetti, who originally conceived the procedure. Their procedure was based on tendons rather than on a tunnel. Dr. Putti, following the idea of Sauerbruch, developed a tunnel in the muscle belly, and that has proved better.

The advantages are as follows: First, there is an appliance which the man does not operate with a shoulder strap. Second, there is direct control, which can be separated from other movements of the arm and can be performed with the arm in any position; this is not true of the hand operated with a shoulder strap. Third, the man has a sense of feeling, which comes from deep muscle sensibility, about the size of an object and its form. These are distinct advantages. Certainly if a man were blind, the method would have a great advantage.

I think that, for a man with a bilateral amputation, the cineplastic method holds great promise. Yet I am not sure, from what I have seen, but that a man properly equipped with hooks can do just as much with his hooks as the man with a bilateral amputation who has had the cineplastic method carried out.

The disadvantages lie in the apparatus; its form certainly is bad for the sensitive nature of some of these people. Dr. Baer and I, in our report to the Army in 1918, pointed out, first, that the procedure was still experimental; second, that it should be done only by surgeons who were very familiar with the method and who had the appliance available; and third, that the surgery is still superior to the appliance. I think those conclusions still hold and may be basic.

Dr. Verne T. Inman, San Francisco, California: I wish to thank Dr. Abbott and Dr. Alldredge for the opportunity of discussing for a few minutes the problem of the cineplastic method of amputation. I feel rather deeply about this subject, since on the surface it appears that this method should be a definite step forward in our search for procedures to increase the function of the artificial hand. However, its success so far has been questionable; and I have heard the surgeon put the blame on the limb manufacturer and the limb manufacturer place the blame on the surgeon, because of the inability to develop a prosthesis which would fully exploit the apparent potentialities of the muscle tunnel. Certainly the responsibility rests as much upon the surgeon as upon the prosthesis manufacturer.

One of the reasons why greater success has not been achieved is that surgeons have forgotten many of the fundamental principles of muscle physiology. This is evidenced by the fact that we have permitted the prosthesis manufacturer to construct an arm, based upon the attempted utilization of the muscle directly to move the fingers. We have failed to recognize the presence of a reciprocal relationship between the laws of muscle contraction and the geometry of the joint. A muscle becomes more powerful as it elongates and loses tensile strength as it shortens. In the body, this decrease in strength as the muscle shortens is compensated by changing the effective lever arm or by the separation of origin and insertion during contraction, as exemplified in "two-joint" muscles. The present prostheses fail in not adequately supplying such a compensatory mechanism, with the result that power of grasp is rapidly lost as the artificial hand is closed. There is no hope, as far as I can see, in utilizing the tunnel directly without the insertion of some compensating mechanism which will duplicate to some degree the mechanism of the human body.

LATERAL SKELETAL TRACTION IN THE TREATMENT OF FOREARM FRACTURES *

BY E. H. WHITE, M.D., AND JEAN M. STEVENSON, M.D., CINCINNATI, OHIO

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The maintenance of the normal width of the interosseous space in fractures of the shafts of the radius and the ulna has long been recognized as essential. The various methods of fixation most commonly employed—such as open reduction with subsequent plating or grafting; threading the fragments over a pin; employing mechanical splints, with multiple-pin fixation and external-bar splinting; and the use of leverage screws, as described by Carrell—testify to the importance of preventing angulation at the fracture level with a resultant loss of supination and pronation. In compound fractures which are draining, and which are not examined until after initial treatment has been started, the orthodox methods are either not applicable, or can be employed only after an unnecessary delay. The authors recognize that, since the advent of the sulfonamides and penicillin, open reduction and metal fixation have been advocated even in the presence of wounds that are not entirely clean. We believe that this is a procedure involving considerable risk, except in carefully selected cases. A method that could be employed effectively and safely would afford obvious advantages.

The secondary closure of wounds which have had careful débridement often may be successfully accomplished within the first week after the injury. This practice would undoubtedly facilitate the healing of wounds, so that in many the introduction of metal at the fracture site would soon be tolerated. However, by that time, callus would be present, and an appreciable delay in treating the fractures would have occurred.

In addition, compound fractures are encountered in which there has been sufficient loss of cutaneous tissues to make secondary closure impossible. Such adjuncts as skin-grafting and relaxing incisions may be employed; but these, too, may fail to prepare the tissues for a safe approach to an open reduction of the fragments before they have become fixed in malposition.

We were interested in employing a method whereby the fragments could be controlled at the earliest possible moment without jeopardizing the healing of the wound. The principle adopted involves the use of a cylindrical screw, inserted through the normal skin to one side of the compound wound and fastened to the forearm fragment most closely adducted to the other bone of the forearm. Portable traction is applied to the screw. The deeper fragment serves to elevate the more superficial fragment, and traction is employed until union maintains the desired position. Reductions are easily obtained, and the wound is accessible for dressings, secondary closure, or grafting, while the fracture is uniting.

After employing lateral screw traction on several old, infected forearm fractures, with good results, we were encouraged to attempt the same principle in elective surgery. Too often when metal plates are employed in fractures of the radius and ulna, they must subsequently be removed, after union has been obtained, because of insufficient soft-tissue coverage. The ease with which a single screw, projecting through the skin, may be removed without anaesthesia has obviated the necessity for a second operation.

PROCEDURE

Under novocain or, preferably, pentothal anaesthesia, a stainless-steel screw, of adequate length and with large threads, is inserted into either the distal or the proximal

* Read before the Tri-State Orthopaedic Society, April 19, 1947.

fragment, as close to the wound as possible without causing infection by extension or by operative contamination. It is of the utmost importance to employ a screw of uniform diameter (with no tapering) and to insert the screw into the fragment which will elevate the other fragment when traction is applied. Obviously, if the fracture is perfectly transverse, traction on one fragment will not affect the other. Fortunately, most of these fractures are slightly oblique, and one fragment can be employed to lever the other. In handling the early cases, the hanging-cast principle was employed, and a stainless-steel wire from a muslin loop about the patient's neck was fastened to the screw head. Because it is difficult for patients to sleep in an upright position for several nights, we now employ a padded long arm cast with a wire bow, resembling a banjo splint, and rubber-band traction. This has been found to be more comfortable and to have greater reliability in controlling

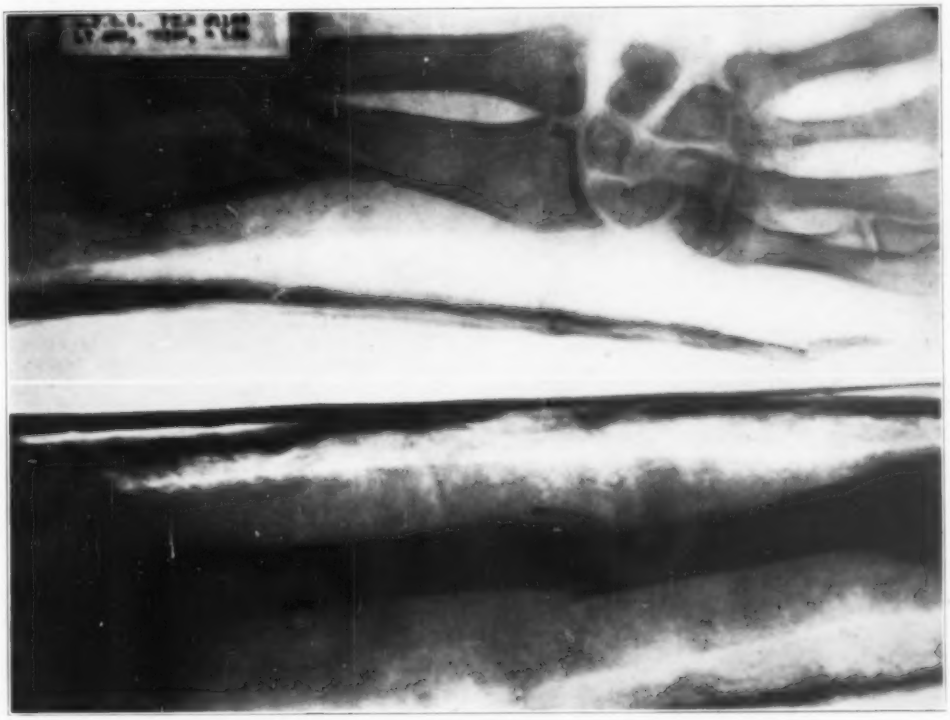

FIG. 1-A

Case 1, W. R. Infected compound fracture of radius twelve days after injury, with complete encroachment upon interosseous space.

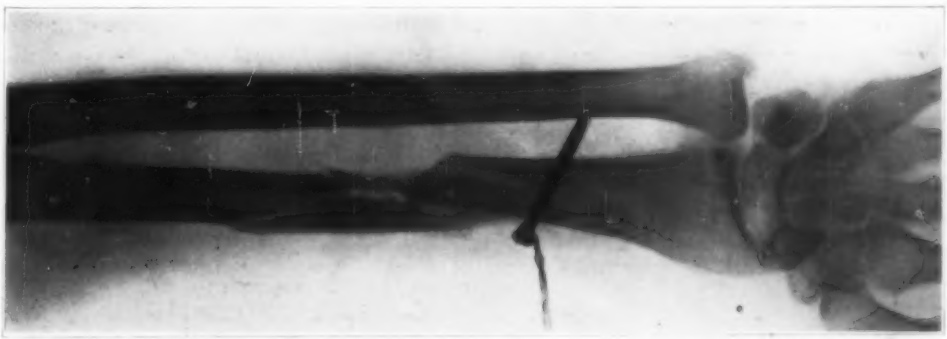

FIG. 1-B

Restoration of interosseous space and good radial alignment, following seven days of traction. The screw does not touch the ulna, but is unnecessarily deep.

the position of the fragments. Traction is maintained until there is roentgenographic evidence of bony callus, at which time the screw may be removed and a second cast may be applied if necessary. We believe that traction should be maintained until fairly firm union is obtained, because of the ever-present danger of a recurrence of deformity by the muscle pull of the pronator quadratus and pronator teres. It is imperative that some contact exist

FIG. 2-A

Case 2, G. M. Loss of interosseous space, following compound fracture of radius of fifteen days' duration.

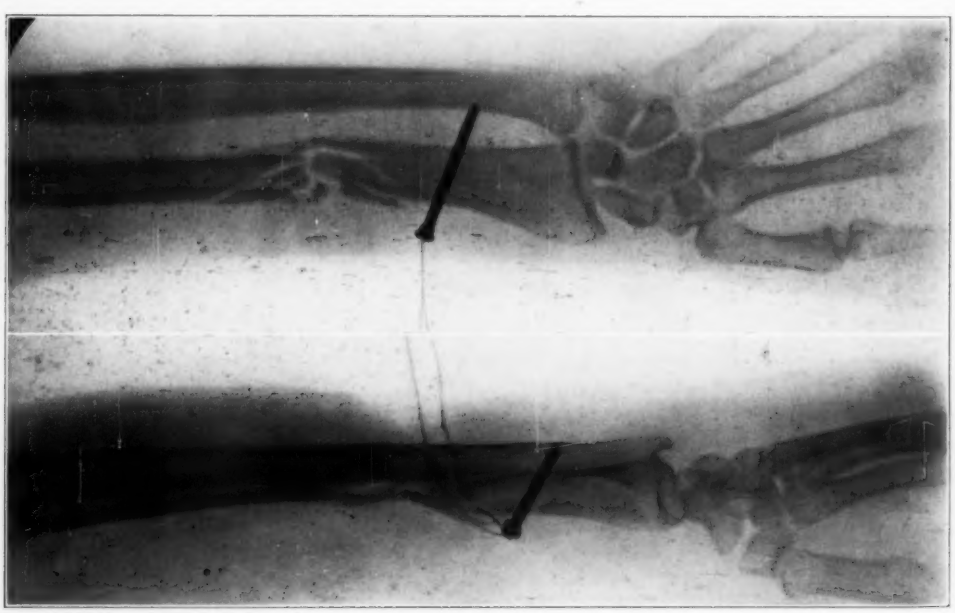

FIG. 2-B

Partial restoration of interosseous space with improvement in position of radial fragments, following five days of traction.

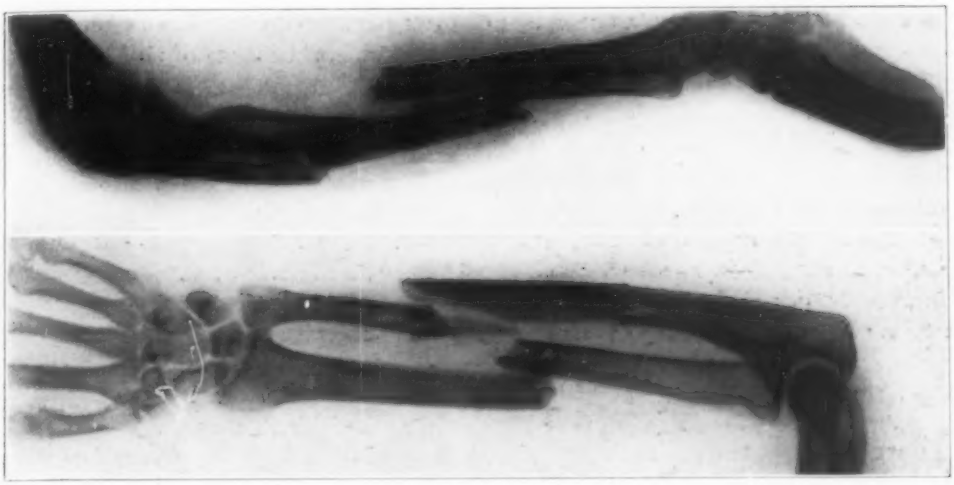

FIG. 3-A

Case 3, D. B. Simple fracture of radius with simple and compound fractures of the ulna.

FIG. 3-B

Three days after insertion of plate and screw traction.

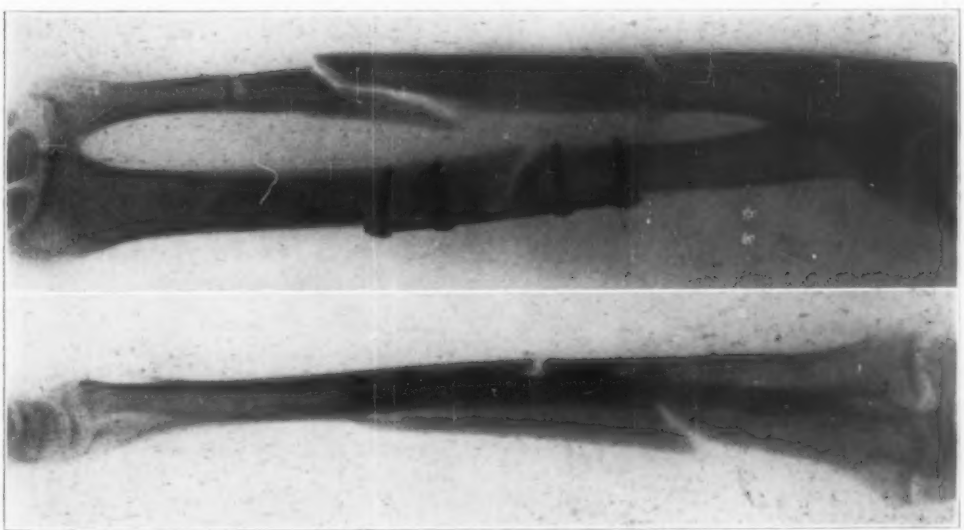

FIG. 3-C

Four weeks after operation, at which time screw was removed and second unpadded long arm cast was applied.

between fragments, inasmuch as complete displacement would result in loss of control of one fragment. However, overpull has not been a problem, because of the limiting effect of the interosseous septum.

CASE 1. W. R., a male, twenty-two years old, entered the Hospital on October 13, 1944, wearing a padded long cast for a rifle-bullet wound of the forearm, received on October 1, 1944. Sulfanilamide had been sprinkled into the wound at the time of injury. The initial surgery, which was carried out elsewhere twenty-

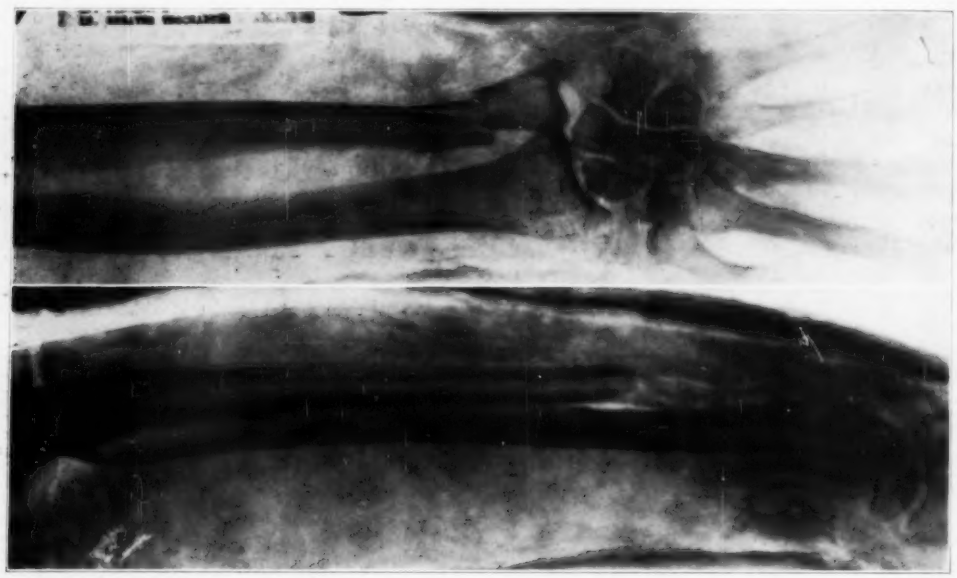

FIG. 4-A

Case 4, H. G. Compound fracture of ulna seventy-two hours after injury. Previous treatment consisted of débridement, packing with vaseline, and application of cast.

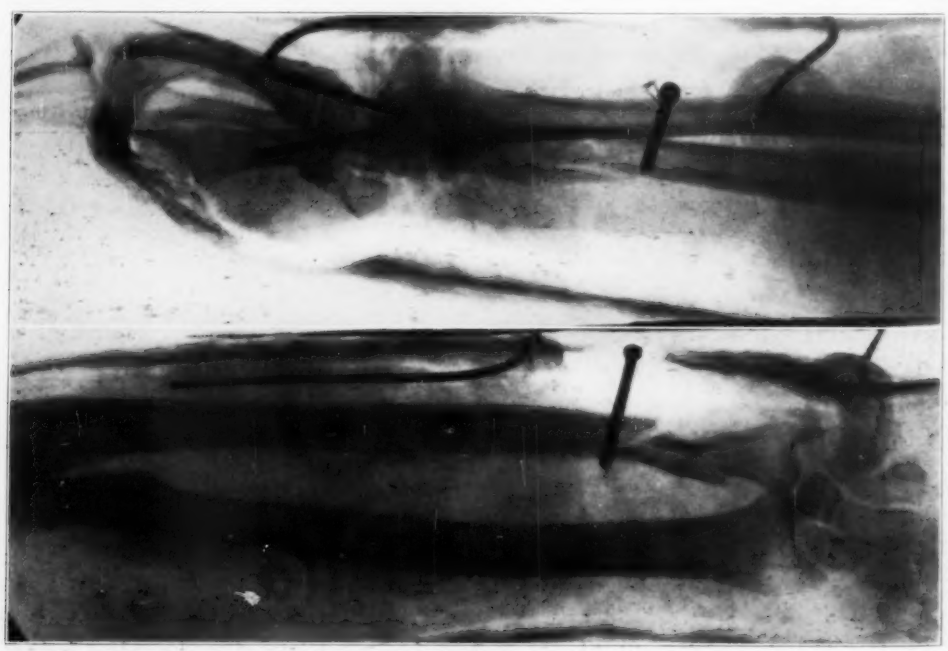

FIG. 4-B

Excellent restoration of interosseous space, following five days of skeletal traction. Screw has been inserted to proper depth.

four hours after the injury, consisted of débridement and fixation in a cast, under pentothal anaesthesia. On October 14, the drainage-soaked cast was removed, revealing an infected wound through the lower forearm. Under sodium-pentothal anaesthesia, a stainless-steel screw was inserted into the distal radial fragment, and gravity traction was instituted by means of a muslin loop around the patient's neck, connected to the head of the screw by a stainless-steel wire loop. On November 6, the screw was removed without anaesthesia, and an unpadded long arm cast was applied. At this time, roentgenographic examination revealed callus and excellent reduction.

FIG. 5-A

Case 5, J. W. Three-month-old Colles's fracture with incomplete radial length and dorsal angulation of distal fragment

CASE 2. G. M., a male, thirty-two years old, entered the Hospital on October 23, 1944, wearing a padded long arm cast for a rifle-bullet wound of the left forearm, which he had received on October 8, 1944. Forty-eight hours after the injury, under pentothal anaesthesia, the "through-and-through" wound had been treated by débridement, dusting of sulfanilamide powder into the wound, and application of a padded, split, long arm cast. On October 24, under sodium-pentothal anaesthesia, the cast was removed, and two foul wounds at the junction of the middle and lower thirds of the forearm were exposed, from which a moderate amount of pus was draining. At this time, a stainless-steel screw was inserted into the radius, and gravity traction was instituted by means of a muslin loop about the patient's neck. On November 14, when there was roentgenographic evidence of callus, the screw was removed without anaesthesia, and an unpadded long arm cast was applied. Good reduction of the radial fragments had been obtained.

CASE 3. D. B., a white male, thirty-three years old, entered the Hospital on May 5, 1945, for a simple fracture of the right radius and a compound fracture of the right ulna, which had been received in an automobile accident, April 23, 1945. Previous treatment had consisted of débridement and application of a cast at another hospital, thirty-six hours after the original injury. On May 8, under sodium-pentothal anaesthesia, open reduction and plating of the radius was done; but, because the ulna had a compound fracture with a draining wound, similar surgery could not be carried out on this bone. Therefore, a stainless-steel screw was inserted into the distal ulnar fragment, and traction was applied by means of rubber bands and a wire bow incorporated in a long arm cast.

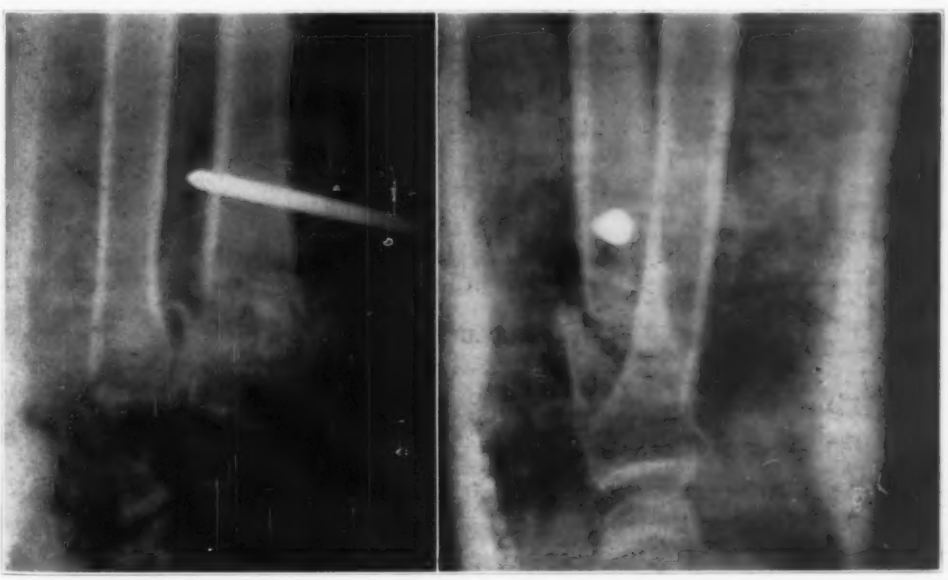

FIG. 5-B

Immediately after operation, with reduction of width of interosseous space secondary to osteotomy.

FIG. 5-C

Improvement in radial alignment, following osteotomy and skeletal traction on radius.

On June 5, there was roentgenographic evidence of callus at the fracture site of the ulna; the screw was removed, and an unpadded long arm cast was applied.

CASE 4. H. G., a white male, twenty-eight years old, entered the Hospital on June 18, 1945, because of multiple wounds of the left forearm and hip, which had been accidentally received on June 15 while he was destroying enemy ammunition. His previous treatment had consisted of débridement of all wounds, without closure, under pentothal anaesthesia. A padded short arm cast had been applied to the left forearm and wrist. On June 19 the arm cast was removed, revealing a draining, tangential wound, measuring two by four centimeters, with a foul, necrotic base on the ulnar side of the lower forearm. Roentgenograms revealed radial angulation of the ulnar fragments with encroachment into the interosseous space. Under pentothal anaesthesia, lateral traction was instituted with a stainless-steel screw and rubber bands over a padded long arm cast. Follow-up roentgenograms on June 23 revealed the normal width of the interosseous space.

CASE 5. J. W., a physician, thirty-five years old, entered the Hospital on January 15, 1946, because of pain, disability, and deformity of the right wrist of three months' duration. On October 13, 1945, the patient fell, suffering simple fractures of the lower end of the radius and the styloid process of the ulna. He stated that, under general anaesthesia, the wrist was manipulated, and a short arm cast was applied which was worn for six weeks. However, roentgenograms, taken on January 16, revealed an incompletely reduced Colles's fracture, with dorsal tilting of the distal fragment and shortening of the radius. Under pentothal anaesthesia, on January 20, osteotomy was performed at the old fracture level, and the dorsal tilting of the distal fragment was corrected. Lateral traction was instituted with a stainless-steel screw and rubber-band traction. On February 8, roentgenographic examination revealed a normal interosseous space; the screw was removed without anaesthesia, and a second long arm cast was applied.

CONCLUSIONS

1. The simple method presented permits early reduction of infected fractures of the radius and ulna. The same principle is now being employed in elective surgery.

2. The use of screw traction has not necessitated any operative attempt to close the original wound.

3. The skeletal traction is discontinued when roentgenographic evidence of callus is present. No anaesthesia has been required to remove the screws.

4. In a small series of cases, there have been no instances of operative infections or overpull.

THE BRIDGING OF BONE DEFECTS

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The bridging of bone defects and bone-grafting for non-union have constituted one of the most important problems of the Orthopaedic Service at Deer Lodge Hospital. This Orthopaedic Treatment Center was organized in April 1944, to treat orthopaedic cases of the three Armed Services, from Manitoba, Western Ontario, and part of Saskatchewan.

From April 15, 1944, to April 15, 1946, 105 patients underwent bone-grafting operations for the repair of bone defects or for non-union of fractures of the extremities. This figure does not include bone grafts for non-union of the carpal scaphoid, or for fusion of damaged joints.

This report has been written, not to extol the merits of any particular graft or technique, but to record the methods used and results obtained at this Center. It is hoped that other Orthopaedic Treatment Centers of the Department of Veterans Affairs will report similar series, so that methods of grafting and results may be compared.

GENERAL OBSERVATIONS

All the patients operated upon were good surgical risks,—young and in good physical condition. This accounts largely for the fact that there were no deaths in the series, although some of the operations, especially those on the upper end of the femur, were quite extensive.

In 85 per cent. of the cases, the injury was caused by a gunshot wound. Accidents of various types, many involving motorcycles, were responsible for the remainder. All but a few of the injuries occurred overseas, and consequently there was an interval of several months between the time of injury and admission to Deer Lodge Hospital.

In the majority of cases, the wounds had either healed or were healing at the time of admission. If a draining sinus was present, an exploration was usually necessary for the removal of a sequestrum, bits of battle dress, or sometimes suture material. In cases in which the wound had healed shortly after secondary suture in the hospitals overseas, three months was the minimum interval allowed between wound healing and the bone-grafting operation. Where there had been a chronic discharging sinus, necessitating exploration, a longer interval—usually from four to five months—elapsed before bone surgery was undertaken. This period is considerably shorter than that allowed after World War I, but it was felt that, because of the more rapid wound healing obtained and the availability of penicillin, the shorter period was justifiable. This proved to be the case, as no failures or loss of the graft resulted from infection in the operative wound in any of the cases which had been healed for three months or more before operation. It is probable that this was due to the routine use of penicillin for several days after every bone-graft operation. This procedure was felt to be justified by the fact that 85 per cent. of the patients had compound fractures resulting from gunshot; and the inconvenience of penicillin administration in the other cases was more than compensated for by the protection gained.

Many of the patients with gunshot wounds had considerable soft-tissue damage, with loss of muscle and scarring of the skin. When it was felt that the operation could

not be done without interfering with the blood supply to a scar near the proposed incision, plastic skin procedures were first carried out, to replace the scar with full-thickness skin. Although the danger of sloughing of scar tissue was appreciated at all times, and procedures were planned accordingly, such sloughing did occur in a few cases, with partial or complete loss of the graft.

Most of the patients with involvement of the femur had been treated by skeletal traction for several weeks prior to immobilization in a plaster spica. Several had tracks of infection where the pin had been inserted; these had to be treated before bone surgery could be done. Healing was accomplished by curetting the infected area and keeping it open with vaseline gauze while it filled in, or by saucerizing the track and allowing soft tissue to fall into it. More of such infections were encountered than had been expected. In most of the cases, a Steinmann pin had been used rather than a Kirschner wire; and it is felt that the larger diameter of the Steinmann pin may have made it easier for organisms to gain access to the bone. Where possible, it seems safer to use a Kirschner wire for skeletal traction.

In all cases of delayed union in fractures of the long bones of the extremities, the limb had been immobilized for at least six months before operation was considered. Unless some union was demonstrable at the end of this period, a bone graft was felt to be indicated to hasten recovery.

Where external immobilization was considered necessary to protect the grafts, plaster-of-Paris splints were used. A padded plaster was applied at the time of operation, and was replaced in from two to three weeks by a skin-tight plaster. For all grafts to the radius and ulna, the plaster extended from the axilla to the metacarpal heads. For grafts to the humerus, a shoulder spica was considered advisable, in view of the fact that these patients were young. A single hip spica was used after bone transplants to the femur; and, if this was considered insufficient immobilization, it was replaced by a double spica, reaching to the knee on the sound side and to the toes on the affected side. For the tibia, plaster extending from the groin to the metatarsal heads was used routinely. These splints were not discarded until the roentgenograms showed that union was well advanced. When the plaster had been removed from the patients with arm grafts, active movements of the joints which had been immobilized were started at once. When the femur was involved, the graft was protected by an ischium-bearing walking caliper for several weeks after removal of the spica, with active non-weight-bearing exercises for the muscles and joints. Following removal of the plaster for a tibial graft, the patient usually walked with crutches for a short time, while doing active non-weight-bearing exercises. When roentgenograms showed that the tibia was strong enough for full weight-bearing, the crutches were discarded.

Tribute must be paid to the medical officers who treated these patients overseas. No gross bone infections were seen at this Hospital. Very few cases of malunion requiring osteotomy were encountered, and length had been maintained satisfactorily in cases with considerable defect in the shaft of one of the long bones. The soft-tissue wounds had all been sutured within a few days, whenever possible, so that soft-tissue scarring was kept at a minimum. All this made the final reconstructive surgery considerably easier.

METHODS OF BONE-GRAFTING

Early in the series, the cortical inlay or onlay graft, with some cancellous bone from the upper end of the tibia, was used in almost every case. Later, when more had been learned about iliac cancellous bone, this type of graft was used more frequently, either by itself or in combination with other methods.

The cortical onlay graft was used twenty-nine times, in the following bones: ulna five, radius two, humerus ten, clavicle two, and femur ten. The technique used was similar to that described by many authors [4,5,6,8,11]. The area of fracture or the bone defect was ex-

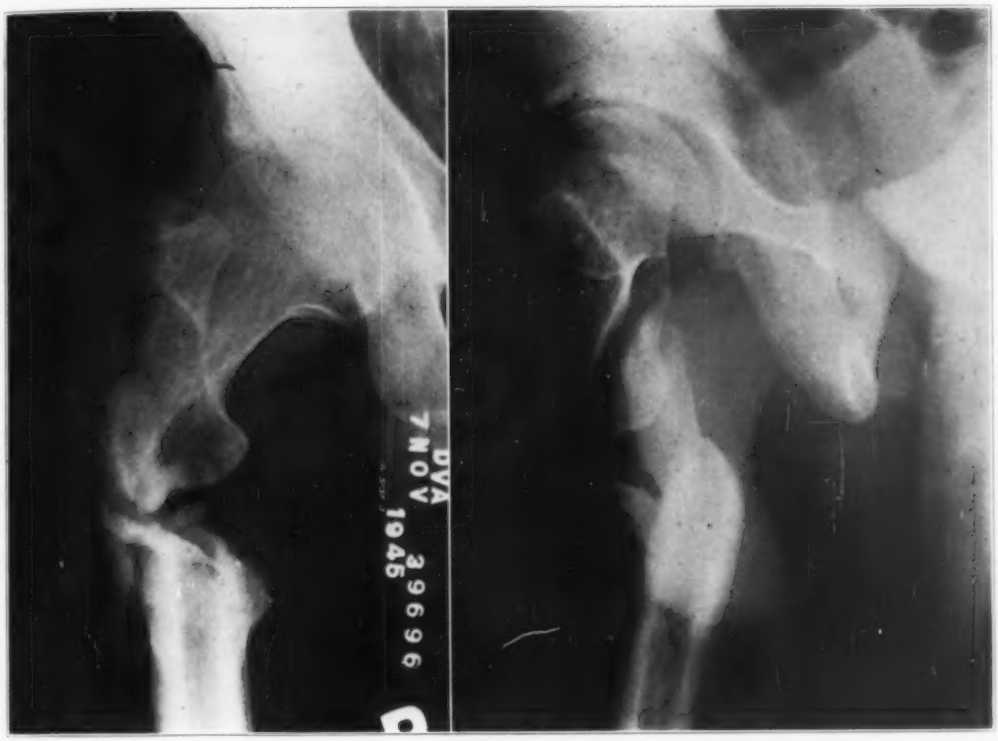

FIG. 1-A

Ununited fracture of right femur, seven months after injury.

FIG. 1-B

FIG. 1-C

Fig. 1-B: Cortical onlay graft and Moore plate in position, four and one-half months after operation.
Fig. 1-C: Femur is united and plate has been removed, seven months after operation.

posed by reflecting the periosteum above and below the wound area, where the bone was normal, and gradually freeing the ends of the fragments from the intervening scar tissue. Reflection of the periosteum was done as conservatively as possible. All scar tissue between the bone ends and usually the very sclerotic bone at the ends of the fragments were then removed. The medullary canal was opened by drilling, if this was considered necessary. The cortices of the fragments were then freshened with an osteotome, until flat enough to receive the graft. The cortical graft was cut from the subcutaneous surface of the tibia, and fixed to the fragments by Vitallium or stainless-steel screws. An overlap of 5 centimeters on each fragment in the arm, and 6.2 centimeters in the leg, was considered the minimum for safety; and more was allowed if possible. Cancellous bone from the upper end of the tibia was then inserted in the defect and around the graft. In the operations performed later in the series, cancellous bone from the ilium was used as well, if enough could not be obtained from the tibia to fill the gap completely. An attempt was made in all cases to have the graft bed as free from scar tissue as possible; in this way it was hoped that the vascularization of the graft would proceed more quickly.

In some situations this graft may be subjected to greater stress than it can reasonably be expected to withstand. In an intertrochanteric fracture or a fracture of the upper shaft of the femur, a spica cannot be molded accurately enough to control all movement at the fracture site; and absorption and fracture of the graft are apt to occur. In four such cases the graft was combined with a metal plate. In the intertrochanteric fractures, the Moore plate was used, with the cortical graft on the anterior surface of the femur. In the shaft, a Lane plate was applied anteriorly and the graft was placed laterally. In two cases, double onlay tibial grafts, one applied anteriorly and one laterally, were used instead of a graft and plate. The results have been equally satisfactory.

The cortical onlay graft has the advantage of great strength and firm internal fixation of the fragments. It must, however, be protected by plaster immobilization until the roentgenograms show that union is well advanced. The greatest strain on this rigid graft is at the fracture line or bone gap. If there is movement within the plaster, absorption and fracture of the graft are very apt to occur. This is particularly true in the ulna; in this bone a rotation strain at the site of the fracture is bound to occur, unless the hand portion of the plaster remains rigid and dry. This is the crux of after-treatment, but patients not under constant supervision are apt to return with the plaster below the wrist soft and moist, and some degree of pronation and supination possible. Two of the five cortical onlay grafts to the ulna failed for this reason.

In the femur, the use of the metal plate may prevent failure, by taking some of the strain from the graft (Figs. 1-B and 1-C).

The cortical inlay graft was used twenty-seven times in this series, in the following bones: metacarpals two, radius one, ulna five, tibia seventeen, medial malleolus one, and lateral malleolus one. The technique used was similar to that originally described by Albee, except that fixation, when used, was by screws of Vitallium or stainless steel rather than by dowelling. In the metacarpals and malleoli, because of the small size of the bones, fixation was secured by stainless-steel wire.

In the tibia, the fracture line was first cleared of all scar tissue, and the ends of the fragments were freshened. In cutting the grafts from the subcutaneous surfaces of both fragments, the electric saw was placed at such an angle that the graft was slightly wider on the periosteal than on the endosteal surface. The longer graft was then placed across the fracture line; if a defect had to be bridged, the shorter graft was cut up and packed into the gap. In most cases the graft across the fracture line was fixed to the fragments by Vitallium screws; in some, if the gap was small, the graft was left free, and a 1.3 centimeter section was removed from the fibula to allow approximation of the bone ends. In all cases, cancellous bone was taken from the upper end of the tibia and placed between the fragments (Figs. 2-A and 2-B).

FIG. 2-B

Gap successfully bridged by sliding-graft technique, nine months after operation.

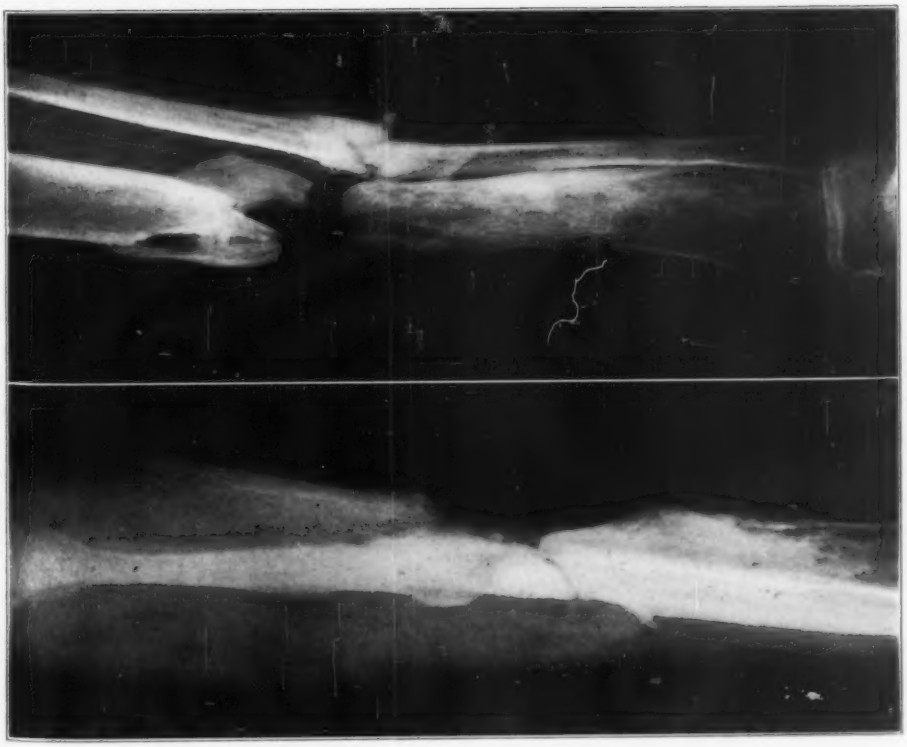

FIG. 2-A

Bone defect, 3.8 centimeters long, in right tibia, sixteen months after injury.

FIG. 3-B

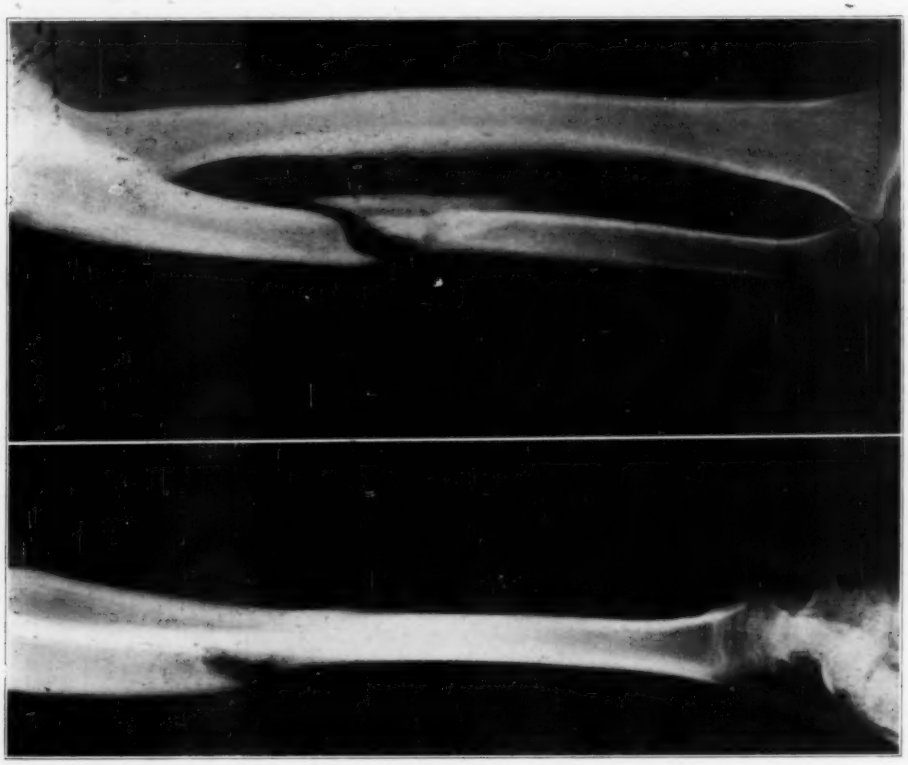

FIG. 3-A

Fig. 3-A: Ununited fracture of right ulna, the result of a gunshot wound.
Fig. 3-B: Seven months after bone graft, in which cancellous bone alone was used, the iliac bone has fused into one mass, and is becoming dense. Most of the excess bone will probably be absorbed.

Fig. 3-A: Ununited fracture of right ulna, the result of a gunshot wound.
Fig. 3-B: Seven months after bone graft, in which cancellous bone alone was used, the iliac bone has fused into one mass, and is becoming dense. Most of the excess bone will probably be absorbed.

FIG. 4-A

FIG. 4-B

FIG. 4-C

Fig. 4-A: Ununited fracture of right ulna, ten months after an unsuccessful attempt had been made overseas to get union by wiring the fragments.
Fig. 4-B: Showing excessive cancellous bone used, two weeks after bone-grafting.
Fig. 4-C: Seven months after operation, ulna has united and excess bone has been absorbed.

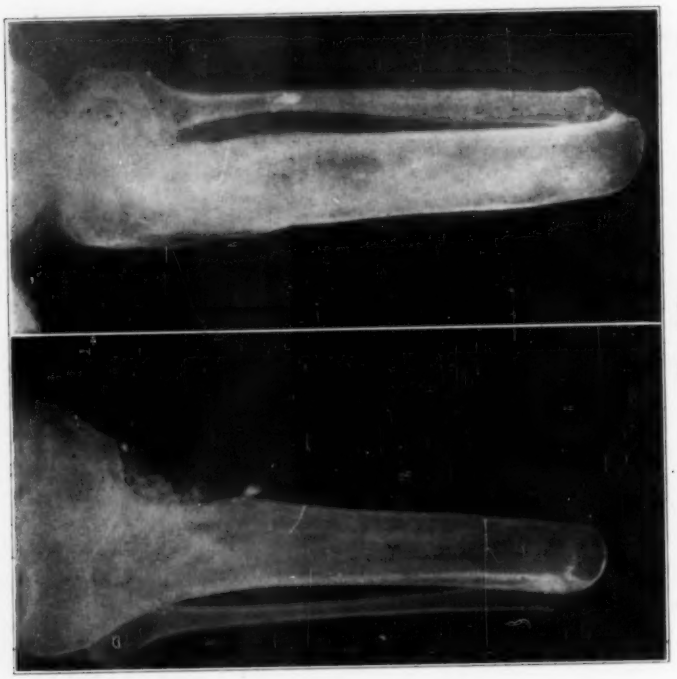

FIG. 5-B

Fig. 5-A: Infected cavity occupying head of tibia, with intermittent discharge since World War I and continuous discharge for a year before operation.

Fig. 5-B: Cavity six months after operation. Wound had healed one month after operation. Patient now wears prosthesis comfortably.

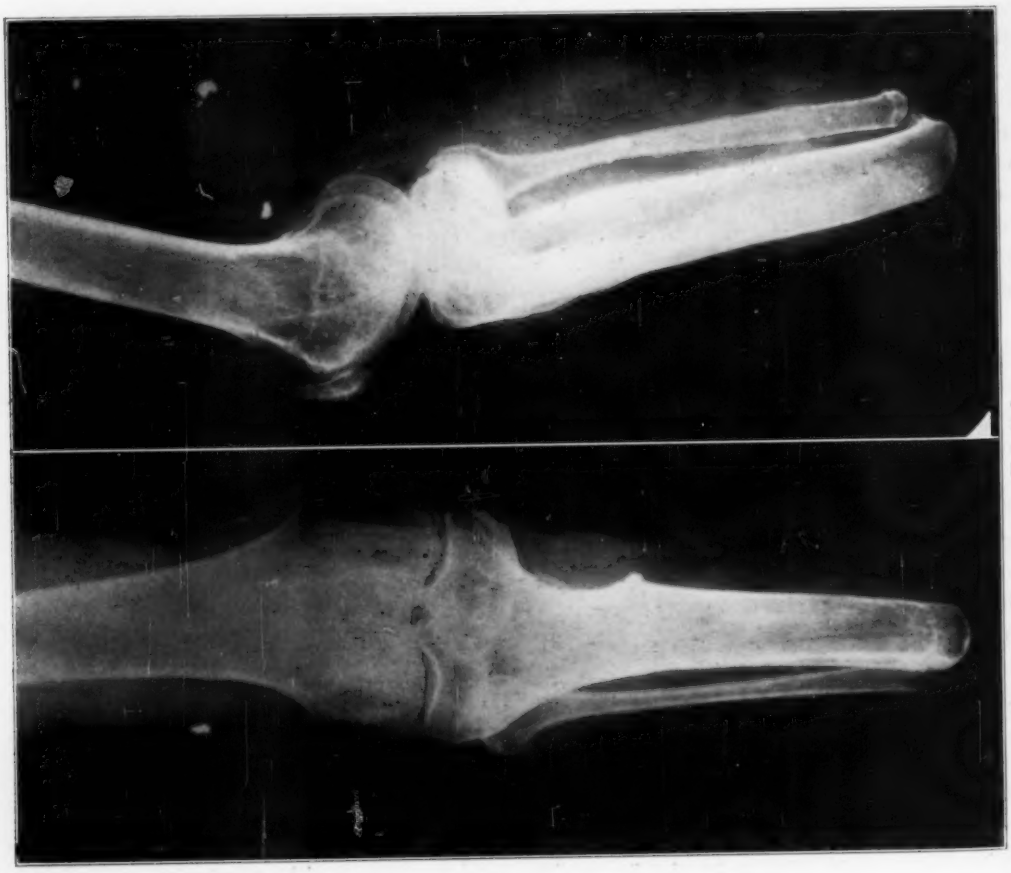

FIG. 5-A

For the ulna, a cortical graft was taken from the tibia, inlaid on the lateral surface, and fixed by metal screws. Considerably more cancellous bone was obtained by this method than would have been the case if the sliding-graft technique had been used. In the metacarpals, a small tibial cortical graft was fitted snugly into a groove in both fragments and held by stainless-steel wire. For the malleoli, the graft was obtained from the upper fragment and fixed across the fracture line with stainless-steel wire.

The diamond inlay graft, described by Albee, was not used.

Cortical-chip grafts were used in only one case. In this, there was non-union of a fracture 5 centimeters from the lower end of the radius, with 1.3 centimeters of shortening. The lower end of the ulna was excised, converted into chip grafts, and packed into the gap between the freshened fragment ends. Good union resulted from this procedure.

Numerous reports have appeared in the literature in the past few years on the use of cancellous-bone grafts. This type of graft can be used in several different ways, and is applicable in certain cases where cortical grafts would not be feasible. It can be used alone to fill gaps in the shafts of the long bones, or for the same purpose after fixation of the fragments with a metal plate. In cases in which there is a partial defect in the shaft, it is a very convenient method of increasing the strength of the bone. In a few cases, a solid block of iliac bone, with one cortex removed, has been used as an onlay graft, and fixed with Vitallium screws. In filling infected bone cavities, where saucerization would have been impossible, it has been most useful.

In all cases in which cancellous bone was used alone, the ilium has been the source of the bone. In approaching the ilium, it is advisable to have the skin incision along the lateral margin rather than over the top of the crest. If this is done, the incision is through fascia and periosteum alone; if it is higher, the muscles of the abdominal wall may be incised, with considerably more hemorrhage. It is advisable to use either the anterior or posterior third of the crest, as the middle third contains less cancellous bone.

When cancellous bone was used alone to fill gaps in the shafts of long bones, slices of the crest, about 0.3 centimeter thick, and the full width of the ilium, were cut with an osteotome. After removal of all scar tissue and the sclerosed bone ends, the slices were placed in the gap. Some were arranged to overlap slightly the ends of the fragments; smaller pieces filled the interspaces. The cortex was not removed from these slices. The grafts were held in place by soft-tissue suture only, and immobilization was by plaster. This method has been used twenty-two times,—fifteen times in the upper limb and seven in the lower limb (Figs. 3-A and 3-B).

In thirteen cases in which bone defects had to be bridged, a metal plate was used to fix the fragments, and cancellous bone was applied to fill the defect [3, 9]. Theoretically, this method would seem to be preferable, in that movement at the gap would be reduced to a minimum, and earlier removal of the plaster immobilization would be possible. This proved only partly true.

In some cases, only a partial defect of the shaft had to be grafted. In these, the bony wall of the defect was freshened, the medullary canal was opened above and below, and strips of iliac bone were laid in the defect as free grafts. The interspaces were filled, as before, with small cancellous blocks, one-quarter inch by one-quarter inch by one-eighth inch in size. As much cancellous bone as possible was transplanted,—even more than enough to restore the original diameter of the shaft (Fig. 4-B). A good result seemed more certain in cases in which this was done than in those in which less bone was used. No plaster immobilization was necessary; but after the lower limb had been grafted, weight-bearing was not allowed until union was well advanced.

This type of graft was used in nine cases,—three involving the upper limb and six involving the lower limb.

The use of cancellous bone to fill infected cavities was a matter of necessity rather than of choice in thirteen cases. These cavities were so situated that saucerization of them

was almost impossible. Some involved the whole or part of the upper end of the tibia; others were so situated in the shaft that, if saucerization had been done, only a narrow bar of bone would have been left to connect the fragments. One case had an infected tunnel, 1.3 centimeters in diameter, through the calcaneus; this had followed the use of a Steinmann pin for traction, in a military hospital. The tunnel had been curetted on two occasions, but the discharge had persisted. Saucerization was obviously impracticable, but filling the tunnel with cancellous bone was an easy procedure and gave an excellent result.

In recent years, several authors [8,12] have described the survival of cancellous-bone grafts in the presence of low-grade infection, and this has been borne out by our experience. If this method is attempted, there must be sufficient healthy skin available so that, when the cavity has been filled, full-thickness skin can be closed over it without tension. If this is not possible, the graft is apt to be completely or partially lost.

In each case the cavity was thoroughly curetted, so that all infected granulation tissue and scar tissue were removed, and bleeding bone was left to form the walls of the cavity. Cancellous iliac bone, finely divided and with all cortex removed, was then placed in the cavity so as to fill it completely (Figs. 5-A and 5-B). In some cases this required a considerable amount of the iliac crest, both anteriorly and posteriorly, but no harmful effects were noted after such extensive removal. If possible, muscle was used to cover the cavity; but if this was not available, full-thickness skin was sutured over it. In the early cases, a ureteral catheter was left in the bottom of the cavity, projecting through the wound, so that the graft could be irrigated regularly with penicillin. Later this was found to be unnecessary, and a penicillin-sulfathiazole powder was substituted. This mixture was applied to the walls of the cavity after it had been curetted, as the cancellous bone was being inserted.

In all cases, penicillin was administered for ten to fourteen days after the operation.

DISCUSSION OF RESULTS

For this report, any bone graft done before April 15, 1946, in which the limb was still immobilized in plaster on December 1, 1946, was considered to be ununited, even though roentgenograms taken at that time showed the graft to be uniting. In any case classified as "united", solid bony union and good functional use of the limb were present on December 1, 1946.

Seventeen of the patients had gaps of 1.3 centimeters or more, in the shaft of one of the long bones, which had to be bridged; four of these were 5 centimeters or more in length.

TABLE I

LOCATION OF BONE GRAFT IN NINETY-THREE SUCCESSFUL CASES

Location of Graft	No. of Cases in which the Graft United	No. of Operations
Metacarpals	4	4
Radius	8	9
Ulna	16	21
Humerus	13	14
Clavicle	3	3
Femur	16	17
Tibia	25	27
Calcaneus	3	3
Medial malleolus	4	4
Lateral malleolus	1	1
Totals	93	103

TABLE II

LOCATION OF TWELVE UNSUCCESSFUL BONE GRAFTS

Location of Graft	No. of Cases in which the Graft Did Not Unite	No. of Operations
Metacarpals	1	1
Radius	1	1
Ulna	2	5
Femur	3	5
Tibia	3	3
Calcaneus	2	4
Totals	12	19

A total of 122 operations were performed on 105 patients in the two years following April 15, 1944. Bony union was achieved in 93 cases, after 103 operations. The bones which were grafted in these successful cases are shown in Table I. Of the ninety-three successful cases, union was obtained in eighty-four by one operation and in eight by two operations; one ulna required three operations before the graft had united. Hence 80 per cent. of the initial 105 operations were successful.

Twelve cases are classified as having non-union, although in four the grafts are uniting, following a second operation. A total of nineteen operations were performed on these patients (Table II).

No conclusions should be drawn from the figures in Tables I and II, which represent all the different types of grafts used, including the cancellous grafts for infected cavities. The results indicate, however, that any patient who underwent a bone-graft operation during this period had an 80 per cent. chance of a successful result from the first operation, regardless of the type of graft used.

Of the patients in whom cortical onlay grafts were used, bony union developed in 85 per cent. after one or more operations. Of the initial operations, 79 per cent. were successful (Table III). This is 1 per cent. less than the average for the whole series. It is felt that the poor results obtained in the radius and ulna require explanation.

The unsuccessful graft to the radius was an attempt to bridge a 7.5 centimeter gap in a patient in whom the upper fragment was too short for fixation of the graft with metal screws. This fragment was split and the graft was laid between the halves. Union occurred at the lower end, but not at the upper, where fixation was poor. In the ulna, one unsuccessful case was a fracture of the upper third, with a dislocation of the head of the radius. The

TABLE III

RESULTS WITH CORTICAL ONLAY GRAFTS

Location of Graft	No. of Cases in which Grafting Was Done	Operations Performed	No. of Cases with Union
Radius	2	2	1
Ulna	4	5	2
Humerus	9	10	9
Clavicle	2	2	2
Femur	6	6	5
Femur with metal plate	4	4	4
Totals	27	29	23

TABLE IV

RESULTS WITH CORTICAL INLAY GRAFTS

Location of Graft	No. of Cases in which Grafting Was Done	Operations Performed	No. of Cases with Union
Metacarpals	2	2	1
Radius	1	1	1
Ulna	3	5	2
Tibia	17	17	16
Medial malleolus	1	1	1
Lateral malleolus	1	1	1
Totals	25	27	22

graft was not strong enough to prevent lateral angulation of the ulna, and broke. The graft has been repeated, combined with a metal plate, and union is occurring. In the other case, two successive cortical onlay grafts, bridging a 2.5 centimeter gap in the middle of the shaft of the ulna, became absorbed and fractured at the center of the defect. This was probably due to inefficient plaster immobilization. After both operations, the patient returned from leave able to pronate and supinate the hand freely, the plaster bar in the palm being soft and useless.

It is likely that, if the radius and ulna had been grafted in a greater number of cases, the results would have been comparable with those of the humerus and femur. There is no reason to believe that the ulna is a more difficult bone than the humerus in which to get union by this method.

The results obtained with the use of this graft in twenty-seven cases are very similar to those obtained by Henderson in 1923. In his series, however, the ulna gave the highest percentage of successful results.

The average time of immobilization of the upper limb was three and one-half months; in the lower limb it was four months.

This method of bone-grafting is regarded very favorably. Some authors feel that the dense graft takes an unduly long time to unite with the fragments. This opinion has not been confirmed by this series; and the greater strength in the shaft, when the graft has united, is definitely a point in its favor.

The cortical inlay graft (Table IV) produced bony union after one or more operations in 88 per cent. of the cases in which it was used. Of the initial operations, 81 per cent. were successful.

The inlay bone graft for the radius and ulna is not regarded as a good operative procedure. Because of the small diameter of the bones, only a narrow graft can be cut. This makes for a weak graft across the fracture line and for relatively poor fixation of the fragments. In none of the cases involving the ulna, was the inlay graft successful the first time used; and, when a second operation was attempted, about one third of the shaft was unavailable for use. This method of grafting for the ulna has been abandoned.

The inlay bone graft gives excellent results when used for the tibia. In the one failure in seventeen cases, the patient had a complete sciatic-nerve lesion with disturbed circulation, and roentgenograms showed no change after nine months. A Stokes-Gritti amputation was done. The average period of immobilization for the tibia was four months. The results indicate that it makes no appreciable difference whether the graft is fixed with metal screws or not, as union occurred in all cases, except the one mentioned. It is apparent that this method of grafting the tibia can be depended upon to give consistently good results.

TABLE V

RESULTS WITH CANCELLOUS BONE ALONE

Location of Graft	No. of Cases in which Grafting Was Done	Operations Performed	No. of Cases with Union
Metacarpals	3	3	3
Radius	4	4	4
Ulna	7	7	6
Humerus	1	1	1
Clavicle	1	1	1
Femur	4	4	3
Tibia	3	3	2
Totals	23	23	20

It is also an easy and apparently successful procedure to use for ununited fractures of the lateral malleolus. A cancellous bone block with a metal screw for fixation is a more satisfactory graft for the ununited medial malleolus, as this bone is usually too small and soft for a groove to be cut into it.

The cortical inlay graft for a metacarpal is a comparatively difficult operation. The diameter of the metacarpal shaft is too small to take an inlay graft large enough to be fixed with metal screws, and wire fixation is relatively unstable.

Cancellous bone alone was used to promote union in ununited fractures in fourteen cases, and to fill defects of 1.3 centimeters or more in the shafts of the long bones in nine cases. This method produced bony union, after one operation, in 87 per cent. of the cases in which it was used (Table V).

These results substantiate the claim of Luckey and Adams that cancellous bone alone can be relied upon to give union in a high proportion of cases. This method was used to treat three ununited fractures and four defects in the shaft of the ulna, and gave a higher percentage of union than was obtained with any other type of graft used for this bone.

The claim, however, that exposure of a greater amount of osteogenic bone produces more rapid union and earlier use of the limb was not verified. In the ulna, the average period of immobilization was seven and one-half months before roentgenograms showed union to be solid enough for the plaster to be removed. This was two and one-half months longer than the average for any other type of graft used for this bone. The additional immobilization is a handicap in the restoration of movement to the wrist and elbow joints. Union may occur more quickly; but, before the soft callus has become firm enough for

TABLE VI

RESULTS WITH CANCELLOUS BONE AND METAL PLATE

Location of Graft	No. of Cases in which Grafting Was Done	Operations Performed	No. of Cases with Union
Radius	2	2	1
Ulna	6	6	4
Humerus	1	1	1
Femur	3	3	2
Tibia	1	1	1
Totals	13	13	9

TABLE VII

RESULTS WITH CANCELLOUS BONE IN INFECTED BONE CAVITIES

Location of Graft	No. of Cases in which Grafting Was Done	Operations Performed	No. of Cases with Union and Wound Healing
Tibia	6	7	5
Femur	2	2	2
Calcaneus	4	6	2
Totals	12	15	9

unprotected use of the limb, more time has usually elapsed than if a cortical graft had been used.

In the metacarpals, this method proved easier and more effective than the cortical inlay graft.

Cancellous bone, combined with a metal plate (Table VI), produced union in 69 per cent. of the cases in which it was tried. The unsuccessful grafts were not repeated with this type of transplant. A defect in the shaft of over 1.3 centimeters in length was present in eight of these cases.

It is interesting to compare the results from the use of cancellous bone alone with those obtained when a metal plate was added. Although the number of grafts done by the latter method is too small to warrant definite conclusions, the addition of the plate would appear to have decreased the likelihood of union. It does, however, have one advantage. In cases in which the graft was successful, plaster immobilization was found to be necessary for an appreciably shorter time than when the plate was not used. The average period of immobilization for the ulna, when grafted by this method, was five months, as compared with seven and one-half months without the plate.

In three of the unsuccessful cases, the cancellous bone was used with a Lane plate, and failure was due to a gap of 0.3 centimeter, which persisted at the center of the plate. Above and below this gap, the cancellous bone fused into a solid mass, which united with the ends of the fragments. This did not happen in any of the cases in which a plate was not used, but whether or not the plate was the cause of the non-union is difficult to decide. It may be, as Luckey and Adams claim, that the plate takes the functional strains which normally pass through the bone, and thus interferes with complete fusion.

It may be concluded that, if cancellous bone alone is used, the chance of union is excellent. If the position of the fragments is difficult to control, a metal plate may be added without appreciably diminishing the expectation of union.

In nine cases, cancellous bone alone was used to strengthen the shafts of long bones in which there was an incomplete defect. This technique was successful in seven of the patients; the grafted bone fused into one mass and to the shaft. In one unsuccessful graft for a partial defect in the lower third of the shaft of the tibia, the cancellous bone had disappeared, as shown by roentgenograms taken several months later. In the other case, a cancellous bone block, approximately 8.8 centimeters long, was laid in an incomplete defect of the femur, but did not fuse with the shaft. Had this block been fixed with a few metal screws, or laid in as thin slices, it would probably have united.

Senior orthopaedic surgeons, in the interval between the two World Wars, found that cancellous bone would occasionally disappear completely from the grafted area. The explanation is obscure, but it would seem to occur particularly in cases in which the graft is not subjected to the normal compression or tension strains of the host bone.

The use of a block of cancellous bone as an onlay graft, with one or both cortices attached, is not recommended. If both cortices are retained, it is difficult to get a flat,

straight graft which is as satisfactory as a tibial onlay graft. If one cortex has been removed, the graft may easily fracture. Cancellous bone, with one cortex removed, was used twice on the ulna, with union in one case.

The use of cancellous bone in obliterating infected bone cavities (Table VII) was successful in 75 per cent. of the cases. Saucerization of the cavities was thought to be impracticable in all of these cases. In some, particularly those in which the calcaneus was involved, amputation seemed to be the only alternative.

Two operations on the tibia were unsuccessful. In both of these, the skin had been closed over the graft under considerable tension and the wounds had failed to heal. The procedure was repeated in one of these cases, and the skin was closed without tension by the rotation of a flap. This graft was successful. The other patient was transferred to a hospital closer to his home, with the cavity still discharging.

One patient, whose calcaneus was involved, had three cancellous grafts, and all failed because of inadequate soft-tissue closure. A below-the-knee amputation was done. The other failure in the calcaneus was the first infected cavity of this series to be treated by bone-grafting. A solid block of cancellous bone was used. This eventually had to be removed as a sequestrum. It is felt now that, had the block been finely divided, the graft might have succeeded.

In each case, the cavity had been discharging for months, and in some cases for years, before being filled with cancellous bone. As was to be expected, the discharge persisted through a small sinus in the wound for a short time after the operation. This diminished steadily in amount in the successful cases. The average healing time after operation was five weeks. Constitutional signs of infection arose in only one case, and these subsided without loss of the graft.

It would be rash to classify these cases as cured, but as yet there has been no recurrence of discharge in any of them. Some of the first patients so treated have been working for one and one-half years, and show no evidence of latent infection.

SUMMARY

Bone-grafting operations, for defects and non-union of the bones of the extremities, were performed on 105 patients at Deer Lodge Hospital between April 15, 1944, and April 15, 1946. Union has occurred in ninety-three cases.

Penicillin was used routinely after every operation, and no graft was lost or failed to unite because of primary wound infection.

In eighty-four cases, or 80 per cent., the first graft was successful.

The cortical onlay graft was used twenty-nine times for twenty-seven patients, and resulted in union in twenty-three, or 79 per cent. of the cases.

The cortical inlay graft was used twenty-seven times for twenty-five patients, and was successful in twenty-two, or 81 per cent.

Cancellous bone alone was used to fill gaps, or to promote union in ununited fractures, twenty-three times for twenty-three cases; union occurred in twenty, or 87 per cent. Combined with a metal plate, it was used thirteen times on thirteen patients, with union in nine, or 69 per cent. It was used nine times in incomplete defects of the shaft of the long bones, and fused with the shaft in seven, or 78 per cent. Cancellous bone alone was used to fill infected bone cavities, with discharging sinuses, in twelve cases. Wound healing occurred in nine cases.

CONCLUSIONS

For ununited fractures, or for short gaps in the shaft of the radius, ulna, humerus, and femur, the cortical onlay graft, fixed with Vitallium or stainless-steel screws, is the most efficient. Cancellous bone should be placed between the fragments and around the cortical graft. In the upper end of the shaft of the femur, it should be combined with a metal plate

or with a second onlay graft. In the ulna, if the size of the gap is 3.8 centimeters or more, or if the fragments are difficult to control, a Lane plate, used with the cortical onlay graft, may prevent absorption and fracture of the graft.

The sliding inlay cortical graft gives excellent results for ununited fractures, or defects of 5 centimeters or less in the shaft of the tibia.

Cancellous bone alone will bridge a bone defect, or promote union in ununited fractures in a high percentage of cases. However, before function can be allowed, longer immobilization must be expected than if a cortical graft has been used. Combined with a metal plate, union may be slightly less certain, but plaster immobilization is shorter. Its most practical use is in filling incomplete defects in the shafts of the long bones.

Infected bone cavities can be filled with cancellous bone and a high proportion of successful results can be anticipated, if full-thickness skin can be closed over the cavity and graft. This method may prove useful in the treatment of osteomyelitis of the tarsal bones.

NOTE: From April 15, 1944, to October 1, 1945, this work was carried out under the supervision of Lieutenant Colonel G. H. Ryan, R.C.A.M.C.

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CARPOMETACARPAL DISLOCATIONS

With Particular Reference to Simultaneous Dislocation of the Bases of the Fourth and Fifth Metacarpals

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Although carpometacarpal dislocations or subluxations of the thumb are not uncommon, those of the base of one or more of the four medial metacarpals are extremely rare. The infrequent occurrence of these dislocations, and the fact that we recently encountered two cases of simultaneous dislocation of the bases of the fourth and fifth metacarpals, have prompted a review of the literature and a tabulation of the reported cases of carpometacarpal dislocation, excluding those of the thumb.

Malgaigne, in 1855, stated that up to that time only three cases of dislocation of the carpometacarpal joints had been reported. The first of these cases was an isolated dislocation of the base of the third metacarpal, reported by Blandin in 1844. The second case, also an isolated dislocation of the base of the third metacarpal, was reported by Roux in 1848; and the third case was an isolated dislocation of the base of the second metacarpal, reported by Bourguet in 1853.

Vigouroux, in 1856, was the first to report a multiple carpometacarpal dislocation,—a dislocation of the bases of the second, third, fourth, and fifth metacarpals; and Rivington, in 1873, was the first to report a case of multiple dislocation of the bases of all five metacarpals.

Burk, in a review of the literature in 1901, found twelve cases of dislocation of the base of the fifth metacarpal; all were in association with other carpometacarpal dislocations.

Stimson, in 1910, stated that cases of isolated dislocation of the base of each one of the metacarpal bones except the fifth, had been reported, as well as combined dislocations of the bases of two or more metacarpals. McWhorter, who, in 1918, reported a case of isolated dislocation of the base of the fifth metacarpal, stated that he had been unable to find any record of a previous case. Many other authors have either omitted reference to these isolated dislocations of the fifth metacarpal or have commented on their non-occurrence or rarity.

In a rather careful review of the literature, a few additional cases of both isolated and multiple (simultaneous) carpometacarpal dislocations have been discovered, which have not been included in previous reviews on the subject. In addition, some inconsistencies have been found in the reporting or crediting of cases in some of these reviews. This is particularly true in articles concerning isolated dislocations of the fifth metacarpal.

Thirteen cases of isolated dislocation of the fifth metacarpal have been reported in the literature [16, 22, 31, 38, 41, 50, 57, 63, 76, 78], the first case having been recorded in 1879.

Among the other isolated dislocations, there have been seven cases of dislocation of the base of the second metacarpal [5, 11, 27, 30, 35, 37, 39]; the first case was reported in 1853. Three cases of dislocation of the base of the third metacarpal have been recorded [9, 65, 66]; the first case was reported in 1844. The first of the three cases of dislocation of the fourth metacarpal [1, 44, 61] was reported in 1868.

The most common of the multiple, simultaneous dislocations are those of the bases of the four medial metacarpals. Thirty-one cases, including the various types of dislocations of the four medial metacarpals, have been reported in the literature [8, 12, 14, 15, 18, 20, 24, 25, 28, 29, 32, 33, 34, 36, 42, 45, 51, 52, 55, 56, 58, 59, 68, 69, 71, 73, 74, 77, 78]; the first case

was reported in 1856. Simultaneous dislocations of the bases of all five metacarpals are more uncommon. Only five cases [40, 46, 60, 62, 75] of this type of dislocation have been found in the literature; the first case was reported in 1873.

Multiple, simultaneous dislocation of the bases of three metacarpals is even more uncommon. Only three cases [1, 26, 69] of dislocation of the bases of the second, third, and fourth metacarpals, and only one case [72] of dislocation of the bases of the third, fourth, and fifth metacarpals have been found in the literature.

Simultaneous dislocation of the bases of two metacarpals is also very uncommon. The first case of dislocation of the bases of the second and third metacarpals was reported in 1877. A total of ten cases can be found in the literature up to the present time [4, 6, 14, 19, 29, 53, 67]. Only three cases of dislocation of the bases of the third and fourth metacarpals [12, 51, 64], and only nine cases of dislocation of the bases of the fourth and fifth metacarpals [2, 3, 13, 47, 54, 70, 78] have been found in the literature. These two types of dislocations were first reported in the years 1895 and 1865, respectively.

Of the various types of multiple, simultaneous dislocations, this paper is particularly concerned with those of the bases of the fourth and fifth metacarpals. Eight of the nine cases of this type of dislocation were found in the foreign literature. The single case found in the American literature is the one reported by Bunnell in 1944. To this number we wish to add two cases, which will bring the total number of cases of this type of multiple, simultaneous dislocation to eleven.

CASE REPORTS

CASE 1. A Coast Guardsman, twenty-three years old, was admitted to the Hospital on July 18, 1945, complaining of pain and swelling of the right hand. He stated that the present condition of his hand was the result of an injury which had occurred about three and one-half months previously (April 2, 1945) when he had struck his right hand against a wall while engaged in a fist fight. The patient, however, had continued to work during the interval, despite the pain and swelling of the hand.

Examination showed a prominence and tenderness over the dorsum of the right hand, which was lo-

FIG. 1–A

FIG. 1–B

Fig. 1-A: Case 1. Roentgenogram showing dorsal dislocation of the bases of the fourth and fifth metacarpals.

Fig. 1-B: Roentgenogram following open reduction of dislocation and external skeletal fixation by means of Kirschner wires.

FIG. 1-C

Roentgenograms six weeks after open reduction, showing complete anatomical reposition of the carpometacarpal articulations.

calized fairly well over the proximal ends of the fourth and fifth metacarpals. A roentgenogram revealed a dorsal subluxation of the bases of the fourth and fifth metacarpals (Fig. 1-A).

Closed reduction was unsuccessful, and, therefore, an open reduction was done under pentothal-oxygen anaesthesia. In order to maintain the reduction, it was necessary to use external skeletal fixation by means of Kirschner wires, inserted transversely through the proximal and distal ends of the affected fourth and fifth metacarpals and the adjacent third metacarpal (Fig. 1-B). With the hand in a cock-up position, light, molded plaster splints, incorporating the ends of the protruding Kirschner wires, were then applied.

At the end of three weeks, the Kirschner wires were removed, but the molded-plaster fixation was continued for a full five weeks from the time of the open reduction. Following this, physical therapy, including whirlpool-bath treatments, was instituted. The result, both anatomically and functionally, was excellent (Fig. 1-C).

CASE 2. A merchant seaman, thirty-one years old, was admitted to the Hospital in an intoxicated state on August 14, 1945. The patient had been celebrating the approach of V-J Day and had injured his right hand, but he did not remember any of the details of the accident. His chief complaints were of pain and swelling of the right hand.

Examination showed swelling and a "dinner-fork" deformity of the ulnar portion of the hand. There was limitation of both flexion of the fingers and grasping power of the hand. The roentgenograms showed a posterior subluxation of the bases of both the fourth and fifth metacarpals (Fig. 2-A).

Under pentothal-oxygen anaesthesia, the dislocation was easily reduced by traction on the extended fingers and maintenance of the wrist in dorsiflexion. Following this procedure, immobilization, by means of molded plaster splints with the hand in a cock-up position, was continued for four weeks. Convalescence was aided by physical therapy and increasingly active use of the hand. The result was excellent (Fig. 2-B).

ANATOMY

The carpometacarpal joints at the bases of the second, third, fourth, and fifth metacarpals are all arthrodial diarthroses, or modified, compound saddle joints with an articular cavity within the capsule of each joint and a movement which is gliding in character. The opposed articular surfaces present alternate elevations and depressions, which form a series of interlocking joints. The articular capsule and the dorsal, volar, and interosseous ligaments unite the articular surfaces. "The articular cavity is a continuation of that of the intercarpal joints; occasionally there is a separate space between the hamate and fourth and fifth metacarpal bones, whereas that between the fourth and capitate is continuous with the common joint." [49]

The movements found at these joints, although slight, serve to increase the effect of those of the transverse carpal and wrist joints. The joint between the fifth metacarpal and the hamate bone somewhat approaches the first carpometacarpal joint in shape and

FIG. 2-A

Case 2. Roentgenograms showing dorsal dislocation of the bases of the fourth and fifth metacarpals.

FIG. 2-B

Roentgenograms following closed reduction, showing complete anatomical reposition of the carpometacarpal articulations.

mobility. It has, however, a greater range of flexion and extension, although its side-to-side movement is nearly as limited as that of the other three medial metacarpal bones. The process of the hamate bone limits flexion of the fifth metacarpal. Motion toward the ulnar side is checked by the strong palmar band which unites the base of the fifth metacarpal to the base of the third metacarpal, and by the strong transverse metacarpal ligament at the heads of the bones. The mobility of the second, third, and fourth metacarpal bones is very limited, and consists almost entirely of a slight gliding upon the carpal bones. Mobility of the third and fourth metacarpal bones is extremely slight, because there is no long carpal flexor directly attached to either. Owing to the close connection of the bases of the metacarpal bones, the radial and ulnar flexors and extensors of the carpus act on all of the metacarpals by their pull on the particular bones into which they are inserted.

Abduction, or movement toward the radial side at these joints, is prevented by the impaction of the second metacarpal bone against the greater multangular. A small amount of adduction is permitted at these joints and is favored by the slope of the hamate and the fifth metacarpal. There is also a slight gliding motion between the fourth and fifth metacarpals, when the concavity presented by the palm is deepened to form the so-called "cup of Diogenes".

MECHANISM OF INJURY

No one type of injury produces dislocation of the proximal end of any one or all of the four medial metacarpals on the distal row of carpals. Direct violence, such as is received in a fall or from a blow, is, perhaps, the most frequent mode of injury. However, in some instances, indirect injuries have been known to cause these dislocations. It is difficult to explain the exact mechanism of these injuries; and, therefore, one can only speculate as to the mechanical forces necessary to produce these dislocations.

In both of our patients we observed that, following reduction of the dorsally dislocated bases of the fourth and fifth metacarpals, there was a recurrence of the dislocations upon palmar flexion of the wrist, whereas the reduction was maintained by dorsiflexion. It is believed, therefore, that a force applied to the dorsum of the hand while the wrist is in a position of palmar flexion is the most likely cause of a dorsal dislocation of the base of one or more of the four medial metacarpals. The reverse of this mechanical force would most likely result in a volar dislocation.

Burk, when attempting to produce carpometacarpal dislocations on cadavera, usually obtained fractures. In his experiments, he found it necessary to cut the anterior and posterior ligaments in order to obtain a dislocation. Shorbe repeated Burk's experiments with similar results. Attempts to produce these dislocations on fresh specimens with the carpus fixed were unsuccessful, unless the anterior and posterior ligaments were divided. A dislocation could then be produced by unlocking the bones with flexion and applying pressure to the bases of the metacarpals.

Hammann noted that the carpometacarpal joints have strong junctions and ligaments, and he stated that luxation of these joints could only occur as a result of special or severe injuries.

Mittler, in referring to the experimental research and cadaver studies by Burk, Biancheri, and Romani, stated that the mechanism which produced carpometacarpal dislocations was usually that of a direct force applied to the bases of the metacarpals, and that the resulting volar or dorsal dislocation was determined by the direction of the force. According to Olper, a force applied to the heads of the metacarpals could cause either a luxation of the bases or a compression of the radial and ulnar aspects, which would augment the concavity or the convexity of the hand, and finally cause a laceration of the ligaments and a dislocation of the affected joints, as experimentally demonstrated by Burk. The relatively frequent occurrence of laceration of the dorsal carpometacarpal ligaments in forceful flexion of the hand has also been noted by Biancheri and others.

CLINICAL FEATURES

The usual symptoms of dislocation are pain, swelling, and impairment of the function of the hand. Objectively, there is marked swelling and deformity. The deformity is variable as to site, depending upon whether the displacement is volar, dorsal, lateral, or mixed (divergent). With the more frequent dorsal dislocation, there is a characteristic "dinner-fork" deformity with the depression in the palm. In a volar dislocation, the palm is markedly thickened, and, different from the dorsal dislocation, there may be present a "spade type" of deformity, analagous to the type of deformity seen in the reversed Colles's fracture. Motion of the joints of the affected finger or fingers and the grasping power of the hand are limited.

DIAGNOSIS

As with most wrist injuries, the diagnosis is based chiefly upon the roentgenograms and their interpretation by one who has a thorough knowledge of the anatomy of the carpus.

TREATMENT

In early cases of carpometacarpal dislocations, reduction by closed methods is usually accomplished without difficulty. In attempting closed reduction, it is essential to maintain manual traction on the corresponding fingers of the metacarpal for a sufficient period before applying local pressure or beginning any other necessary manipulation. Canavero and others also stress the importance of applying traction to the fingers and countertraction to the wrist, accompanied by pressure and counterpressure over the palmar and dorsal aspects of the hand at the site of the dislocation.

In late cases, reduction may be very difficult, and sometimes is only possible by an open operation. In regard to the difficulties of late reduction, Shorbe states that unreduced carpometacarpal dislocations do not always produce serious disabilities. Burmeister, and Roberts and Holland, also report good function in some cases in which satisfactory reduction was not obtained. Bunnell, however, states that "reduction is necessary to restore muscle balance and proper mechanics in the hand". Serious consideration should, therefore, be given to old unreduced dislocations before an attempt is made at reduction, particularly open reduction, as the result may be only an improvement in the appearance of the hand, but no actual improvement in its function. This would be particularly true for those patients in whom full restoration of function of the hand is not too important.

Following reduction of a carpometacarpal dislocation, immobilization with molded plaster-of-Paris splints should be maintained for from two to four weeks, depending upon the ease both of reduction and of maintenance of the reposition. In old unreduced dislocations, particularly when open operation is required, external skeletal fixation with Kirschner wires may be necessary to maintain the reduction. In such cases, the wires are inserted transversely through the bases and heads of the dislocated and the adjacent, normal metacarpals. The hand is then immobilized with a light, molded plaster-of-Paris dressing, in which the projecting ends of the wires, capped with corks, are incorporated. Following the period of immobilization, recovery is facilitated by physical therapy.

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PRIMARY CLOSURE OF COMPOUND-FRACTURE WOUNDS

With Immediate Internal Fixation, Immediate Skin Graft, and Compression Dressings *

BY ARTHUR G. DAVIS, M.D., ERIE, PENNSYLVANIA

A review of fifty consecutive cases of compound fracture was presented to this Association in 1942 by Davis and Fortune. The treatment consisted in immediate débridement, metallic internal fixation, skin-grafting, and compression dressings. The previous practice of leaving compound-fracture wounds open, and thus treating deep tissues in the same general manner as superficial tissues, had seemed illogical to the writer; however, routine primary closure had been considered to be precluded by the current hazards of local and general sepsis. Four physicochemical factors were pointed out as being normal for the skin, but devitalizing for deeper tissues,—whether bone, tendon, muscle, joint structures, or other soft parts. The surgical principles of compression and exclusion of air from the deeper tissues are supported by evidence in medical literature, dating back as far as the seventeenth century and including significant contributions from Gamgee, Ollier, Larrey, Arey, Blair, Orr, and Koch; the orientation of these principles has varied, however, as surgery has passed through successive stages of pre-antiseptic, antiseptic, aseptic, and bacteriostatic techniques. The innovation of immediate closure was designed to restore the normal environmental state of the deeper cells; their innate defense mechanisms were considered to be of greater therapeutic value than the action of a bactericidal agent. Results in the fifty reported cases were good enough to warrant continuation of this type of treatment.

The present report is based upon a series of 150 consecutive cases of compound fracture **, observed during the eleven-year period from 1936 through 1946. During the first five years, when neither sulfonamides nor penicillin were available, twenty-eight cases were treated. In the next four years, eighty-three cases were treated with sulfonamides. In the final two years, thirty-nine cases were treated parenterally with penicillin; in addition, in these cases a sulfonamide was dusted into the wound. During the last five years a blood bank has facilitated the generous use of transfusions, and a high-protein diet has been prescribed.

Except for modifications attending the advent of the newer bacteriostatic agents, the blood bank, and the high-protein diet, the program of treatment described in 1942 has undergone no important change. Greater experience, however, has taught the value of a *more radical excision* of questionable skin. With the adoption of this policy, it has been possible to reduce the incidence of sloughing of the wound edges and subsequent infection. Improved techniques in the transfer of split grafts, together with the use of the Padgett dermatome, have facilitated the grafting of large denuded areas.

In the 150 cases of this series, there were fifty-five compound fractures of the tibia or of both bones of the leg, and fifty-two of the fingers or hand. The humerus was fractured in eleven instances, one or both bones of the forearm in fourteen, the femur in two, and other bones in five. Twenty-five of the fractures involved joints; among these were included twelve ankles, five elbows, three knees, and two wrists. There were four deaths; of these two resulted from pneumonia, one from embolism, and one from gas

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**These cases were treated on the Services of C. W. Fortune, M.D., Michael Skovron, M.D., and the writer, at the Hamot Hospital, Erie, Pennsylvania.

gangrene. One above-the-knee amputation was necessary because of the development of gas gangrene.

One hundred and thirty-one, or 87 per cent. of the wounds, healed by first intention. Sloughing of the wound edges occurred in thirteen cases, some of which became infected. Drainage persisted in one tibia for two months, but the bone united in six months. One plated tibia showed healing of the soft tissues by first intention in two weeks; drainage after three weeks; the development of a diffuse osteitis, requiring removal of the plate and sequestrectomy; and finally non-union. This is now being treated by bone-grafting for the second time, a first graft having been unsuccessful. This case is an outspoken failure and defies explanation. One plated tibia exhibited a sloughed skin flap, about three by six centimeters in area, located directly over the plate. The plate was removed after union occurred, and the patient returned to work six months after the injury. Chronic osteomyelitis developed in another plated tibia and the case passed out of our hands; the outcome is unknown. One fracture of both bones of the forearm showed drainage when first dressed, two weeks after the injury, and a sequestrectomy was required; in nine months the patient had regained complete function of the forearm.

Twenty-nine tibiae were fixed by plates or by Vitallium screws alone, immediately after admission. Eight others were plated after the soft tissues had healed by first intention. Three cases required bone grafts. In four, union was delayed or otherwise faulty. A total of twelve cases had skin defects, requiring large grafts. This is exclusive of fingers, in which defects are frequently closed with full-thickness grafts. Farmer and Mathewson have shown that extensive avulsed skin flaps may be used to cover defects.

About mid-way in the series it became apparent that the most frequent cause of failure of healing by first intention was the attempt to preserve questionable skin. It is now realized that, notwithstanding careful technique applied to the deep tissues, questionable skin edges jeopardize the entire result long after the deep tissues have healed. One of three methods is therefore used, its selection depending upon the demands of the individual case: (1) When adequacy of the circulation in a skin flap is doubtful, the tourniquet is removed; if vitality of the flap is not demonstrated, the flap is resected. (2) When longitudinal flaps can be mobilized and drawn together to cover the denuded area, this is done in preference to placing a split graft over the defect; and the defect caused by the shifting is covered secondarily by a split graft. (3) Frequently it is possible to bring the wound edges together without tension by undermining them and using relaxation sutures of stainless-steel wire. In no case has there been a noticeable reaction to the wire.

It is sometimes impossible and frequently inadvisable to do combined immediate treatment of shock, débridement, internal fixation and closure. For this reason several different approaches, depending upon the immediate requirements of the individual patients, are outlined in the case reports.

The first case to be described illustrates the severe type of injury in which immediate operation plus immediate shock treatment go hand in hand.

CASE REPORTS

Case 1 (M.A.). On July 1, 1942, the patient was underneath a magnet, carrying a ton of steel scrap, which accidentally became demagnetized. The patient sustained an amputation just below the right knee, a deep lacerated wound of the right forearm with avulsion of most of the extensor muscles, and a compound fracture of the left femur. Emergency wire tourniquets were applied to the three injured extremities, and the patient arrived at the Hospital thirty minutes after the accident. The treatment included an immediate Callander amputation of the right thigh; immediate débridement of the right forearm wound, with primary closure of the skin and compression dressings; and immediate débridement of the compound fracture of the left femur, with the application of Kirschner wire traction and a Thomas splint. The patient's hemoglobin was 57 per cent. One thousand cubic centimeters of plasma was given during the initial surgery; approximately 4,000 cubic centimeters of blood, plasma, and glucose solution, and a total of six cubic centimeters of adrenal cortex were given during the first two days. The level of sulfadiazine in the blood was maintained at about eight milligrams per 100 cubic centimeters for two weeks.

Two months later there was no evidence of union of the left femur, and a sliding bone graft was applied. Four months later a typical transplantation of flexor tendons to the remains of the extensors in the right forearm was carried out. Nine months after the accident the patient was discharged home with an artificial limb. Seventeen months following the accident, he returned to work. He has since remained uninterruptedly at his job of operating a machine tool.

Immediate skin coverage of the right forearm, after careful débridement, paved the way for the reconstruction and future function of the right hand. The three wounds were clean and dry at the first dressing, two weeks after the injury.

The second case demonstrates the value of immediate, thorough débridement plus immediate skin coverage.

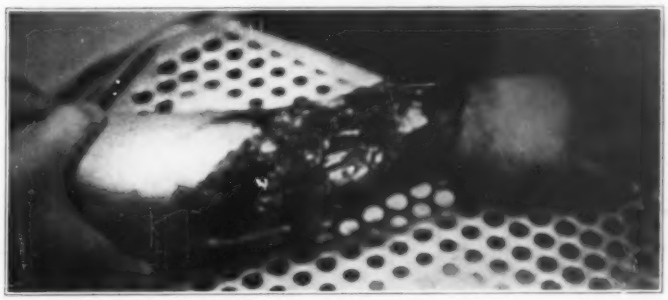

FIG. 1-A

Massive avulsion of extensor muscles and skin of forearm.

FIG. 1-B

First dressing, two weeks after primary suture and split-thickness skin graft.

CASE 2 (L. K.). On June 16, 1943, the patient's right forearm was caught between the roller and the belt of a conveyer system. Most of the extensor muscles were avulsed, and the skin defect measured about four by seven inches (ten to eighteen centimeters) (Fig. 1-A). About four inches of the ulna and radius were laid bare, and a strip of periosteum, one-half inch wide and four inches long, was torn from the radius. The remains of the extensor muscles were debrided, and the skin edges were resected in the usual manner; the tourniquet was removed to determine the viability of remaining deep tissues and skin, and was then reapplied. The long extensor and the abductors of the thumb were uninjured. The middle of the wound was sutured; the rest of the defect was covered by a split-thickness skin graft, three by eight inches in size, taken from the left thigh. Sulfanilamide crystals were dusted into the wound, and a cast was applied over compression dressings of sterile gauze fluffs and sea sponges. The patient received 500 cubic centimeters of plasma during operation and 1,000 cubic centimeters of glucose afterward; his blood sulfadiazine level was maintained at between five and ten milligrams per 100 cubic centimeters for a week.

At the first dressing, two weeks after injury, the wound was clean and dry (Fig. 1-B). The hospitalization period was seventeen days. Three months later a typical flexor-tendon transplant for drop wrist was performed. The patient began light work five months after injury; two months later he returned to his former occupation of running a coal-loading machine.

In both Case 1 and Case 2 the injuries were caused by machine-shop accidents. It has been the author's experience that these wounds are not particularly dangerous as regards infection, although they may be greatly soiled with grease and foreign bodies.

The next case illustrates a combination of immediate treatment of shock, immediate wound closure, and delayed internal fixation.

CASE 3 (J. S.). In a street accident a man, fifty-six years old, was knocked over by an automobile. He sustained compound fractures of the right tibia and fibula; a ragged laceration of the middle third of the right leg, exposing bone; a right Monteggia fracture with the ulna broken at two levels; a dislocation of the right shoulder; a fracture of the right innominate bone and the sacrum; a fracture of the right transverse process of the fourth lumbar vertebra; and fractures of fifth to tenth ribs, with depression of the chest and subcutaneous emphysema.

Immediate treatment consisted in the administration of plasma; débridement and closure of the compound leg wound, which measured three by five inches (eight to thirteen centimeters); casting alone for the fractures; reduction of the shoulder dislocation; and compression dressings for the forearm and leg. During the first two days the patient's condition was precarious; he received 50,000 units of penicillin every three hours, one unit of blood, and about 4,000 cubic centimeters of 5 per cent. glucose in saline. After two weeks, devoted chiefly to treatment of the chest injury, an attempt was made to treat the fractured ulna with an intramedullary Kirschner wire; this was unsuccessful because of an old fracture of the ulna. One week later, a double Vitallium plating of the tibia was done; and five weeks later a bone graft of the ulna was performed and the radial head was reduced and retained by means of a fascial strap, according to the method of Speed and Boyd. The arm and leg casts were removed five months after the accident, and physiotherapy was then carried out for two months. The patient returned to work as a foreman, six and one-half months after the injury.

All fracture treatment was delayed by the precarious condition of the patient on admission. Immediate treatment of shock was imperative. Locally, the most important initial objective was healing of the compound wound by first intention; this was attained two weeks after the débridement, primary suture, and application of compression dressings.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Appearance of gunshot wound on admission, six hours after accident.

FIG. 2-D

Appearance immediately after operation, following removal of accessible bone and lead fragments, and partial internal fixation.

The fourth case illustrates a distinctly borderline type, in which survival of an extremity seems extremely questionable without primary suture, immediate skin-grafting, and compression dressing; and in which survival of the individual may be jeopardized if immediate amputation is not carried out.

FIG. 2-E

Appearance of wound at time of first dressing, two weeks after débridement. An immediate split-thickness skin graft had been applied.

CASE 4 (J. M.). In December 1942, the patient's left forearm was wounded by a soft-nosed bullet fired from a deer rifle; after penetrating the flexor surface, the bullet exploded. The appearance of the wound on admission of the patient, six hours after the injury, is shown in Figures 2-A, 2-B, and 2-C. The hand was warm, with scattered areas of intact sensation. Two units of plasma were given, and immediate débridement was carried out. The muscles had been converted to a pulp; they were spooned out, together with fragments of lead and bone, down to sound tissue. The dorsal defect was sutured flap to flap; the medial defect was covered with a split graft, four by five inches in size, taken from the inside of the thigh; and the fragments of the ulna and radius were brought into approximate alignment, one being fixed with a screw and the other with a mattressed wire suture. A compression dressing, consisting of gauze fluffs and sea sponges, was applied, together with a plaster splint. All three attending orthopaedic surgeons took part in the operation.

The status of the wound at its first dressing, two weeks after the injury, is shown in Figures 2-D and 2-E. The level of sulfadiazine in the blood was maintained at five to eight milligrams per 100 cubic centimeters

and several transfusions were given. Three weeks later a hemorrhage from the wound edge was controlled by compression dressings; on the following day, profuse bleeding necessitated ligature of the dorsal interosseous artery; two weeks later another hemorrhage required tying of bleeding points. During this period

FIG. 3-A
Roentgenogram shows shattering fracture of frontal and nasal bones.

FIG. 3-B

FIG. 3-C

Fig. 3-B: Appearance at admission, after head-on automobile accident, with considerable ooze of cerebrospinal fluid and brain. The patient is unconscious. Immediate débridement and primary closure were carried out.

Fig. 3-C: Shows appearance at time of first dressing and stitch removal, two weeks after the accident.

several transfusions were given. The patient was discharged from the Hospital, with a draining sinus, on February 29, 1944, two and one-half months after the accident. A pedicle skin graft was done two and one-half years after the injury. The radius united solidly without a bone graft; only fibrous union developed in the ulna. The fingers are contracted, but retain patches of sensation in the distribution of all three nerves.

What the results in ten such cases would be is indeed problematic. The dilemma posed by such a case is the choice between sacrifice of the hand and risk of the individual's life. The availability of penicillin and whole blood persuaded us to attempt salvage of the hand in view of the realization that any kind of hand, even if nothing more than a paper weight, is more satisfactory than any kind of prosthesis. If the hand has sensation and if, after primary union or reconstructive bone surgery, it can be moved about by satisfactory supporting structures, the risk to the individual seems justified. In this case, the drainage and the subsequent sinus came from a wound on the posterolateral aspect of the forearm; this wound was so small that we neglected to treat it primarily. It seems quite impossible that this hand and forearm could have survived with any kind of open treatment, without skin coverage or compression dressings.

The next case illustrates an unusual and unpredictable complication, in which immediate primary suture and conservative fracture treatment seem essential to survival of the extremity.

Case 5 (R. S.). While playing in a junk yard, an eight-year-old child was knocked down by an iron flywheel, weighing two tons. The flywheel passed over both legs, pinned the child down for half an hour, and was finally removed by means of a jack and crowbars. When seen in the accident room within an hour, the patient was in severe shock and showed compound fractures of the shafts of both bones of both legs, with severe deformity and fish-belly appearance of the lower half of the legs and the feet. The treatment consisted in immediate administration of plasma, débridement, primary suture, manipulative reduction of the fractures, and the application of compression dressings.

In the right leg spontaneous union, in good alignment and apposition, occurred within six weeks. The fracture of the left leg failed to unite. Five months after the accident, a sliding bone graft was performed. This failed to result in union, however; subsequently a dual bone graft, utilizing a typical onlay from the right tibia and the shaft of the left fibula, was carried out, with eventual union. The patient also required a lengthening of the heel cord on the grafted side. He was walking without support, eighteen months after the accident. Three years after the injury he had full function, with no deformity of either leg.

Since both legs were injured almost identically, each acted as a control for the other. At the time of the dual-graft operation, it was observed that the area of increased density in the distal fragment was completely devitalized; this bone was wholly devoid of circulation. Probably this was a result of the severe crushing injury and a cause of the original non-union, as well as the failure of the first bone graft.

The next case illustrates application of the same therapeutic principles to compound injuries of the skull, involving cerebrospinal fluid and brain ooze.

Case 6 (S. K.). A truck driver was in a head-on collision, his face being driven against the windshield frame. On admission to the Hospital he was unconscious; there was considerable ooze of cerebrospinal fluid and brain, an irregular lacerated wound of the forehead, and a crush fracture of the nasal and frontal bones (Figs. 3-A and 3-B). The status at the time of the first dressing, two weeks after the injury, is shown in Figure 3-C. The treatment consisted of débridement, intranasal correction of the fractured nasal bones, primary suture after frosting with sulfanilamide, and application of a compression dressing which included gauze fluffs and a sea sponge. No anaesthesia was necessary. One month after the accident, the patient returned to his regular work as a truck driver.

The seventh case illustrates the advantage of primary closure when a joint is so severely disrupted that arthrodesis is inevitable, and no immediate treatment of the fracture is indicated, other than mere approximation and the application of a skin-fitting plaster and a compression dressing.

Case 7 (G. K.). On March 6, 1944, while painting, the patient fell from a ladder, injuring his ankle. His injury on admission to the Hospital, three hours later, is shown in Figures 4-A and 4-B. The treatment included

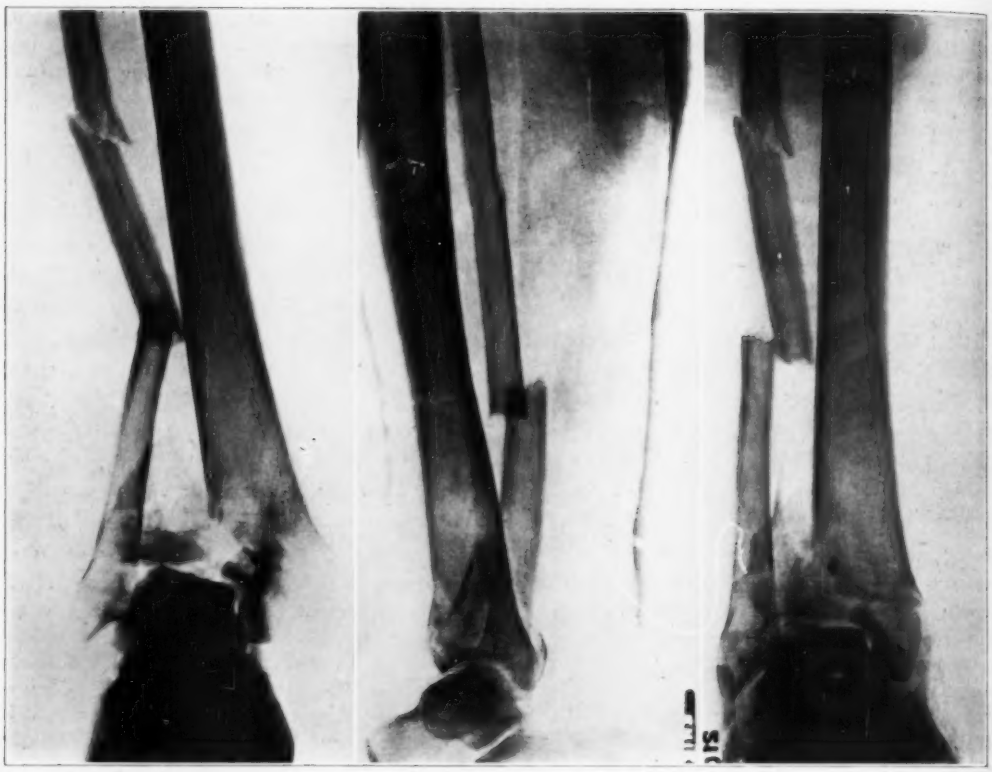

FIG. 4-A

Roentgenograms show typical complete fracture-dislocation. No attempt at exact reduction has been made.

FIG. 4-B

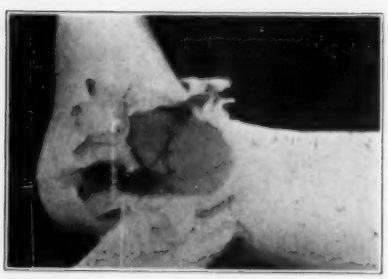

FIG. 4-C

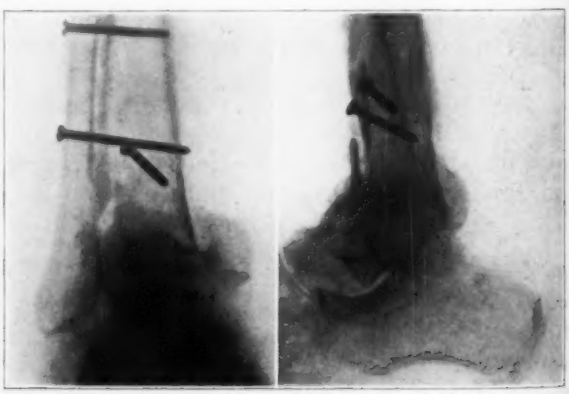

FIG. 4-D

Fig. 4-B: Appearance of ankle on admission, three hours after fall from ladder. Treatment consisted of immediate débridement, saline irrigation, primary suture, and compression dressing.

Fig. 4-C: Appearance of wound at first dressing, two weeks after injury.

Fig. 4-D: Roentgenographic appearance, four months after arthrodesis and tibiofibular synosteosis.

immediate administration of plasma and maintenance of the sulfonamide level in the blood at five to ten milligrams per 100 cubic centimeters. Since the ankle joint was completely disrupted, no studied attempt was made to reduce the fragements accurately. The local treatment consisted of immediate débridement, irrigation with saline solution, primary suture, and the application of a compression dressing with gauze

fluffs, skin-fitting plaster, and elastic webbing bandage. Arthrodesis of the ankle and tibiofibular synosteosis were performed on April 24, seven weeks after the injury. Two weeks later the wound was clean and dry (Fig. 4-C). The result four months after arthrodesis is shown in Figure 4-D. Three years after injury the patient has a stiff ankle, with good function of the leg and foot.

The importance of immediate closure in hastening the subsequent reconstructive surgery is obvious.

DISCUSSION

Because of variables involved in the individual case, it is extremely difficult to evaluate the merits of any single approach to the treatment of compound fractures. The kind and degree of contamination, the size and nature of the skin defect, the amount of bone exposed and the degree of shattering, the amount of blood loss, the degree of shock, the presence of other injuries, and the age and state of health of the individual prior to the accident,—all have a bearing on the outcome. It is possible, however, to evaluate certain general features from a study of the facts in a significant number of consecutive cases. Recent accounts of the results of delayed suture seem significant, but they are limited largely to battle casualties in which primary suture is impractical and hazardous. If the armamentarium and ability are at hand for execution of the proper careful débridement, internal fixation, skin-plastic operation, compression dressing, and treatment of shock within the usual time limit, delayed suture seems to add to the risk rather than to diminish it.

In the present series, the two cases of gas infection, one fatal and the other requiring amputation, are open to question. Whether these patients would have survived under a program of open treatment is speculative. The fatal case was that of a middle-aged school teacher whose tibia was soiled by implantation in the ground in the country. The wound was debrided; the tibia was plated; and a primary suture was done. Within thirty-six hours, fulminating gas gangrene developed and extended above the lower extremity; death occurred within forty-eight hours of the injury. At the first warning of high temperature the cast was removed, and crepitation was noted around a pinhole wound in the posterior aspect of the leg, which had been completely overlooked at the time of primary suture of the more obvious and severe wound. The case requiring amputation was a compound fracture-dislocation of the ankle, in which the talus was partly avulsed and in which it had seemed clear to the operator that, unless primary suture were executed immediately, a mid-leg amputation would be imperative. High temperature and crepitation immediately above the ankle, plus a positive culture, led to a Callander amputation.

Balanced against these two disasters are the remaining cases of the series: 146 living patients, including 131 whose wounds have healed by first intention. Fifty-six of these had compound fractures of the tibia with protrusion and soiling of the fragments; some resulted from street and some from rural accidents. The majority of the patients obtained union and function as promptly as though they had had simple fractures. In these fifty-six cases the penalties of open treatment, whether of delayed suture or of the Orr type, would have included the hazard of prolonged exposure of cortical bone to air; the usual subsequent sequestration of exposed cortex; the frequent non-union, later requiring bone-grafting under most unfavorable conditions; the almost inevitable mixed low-grade infection by putrefactive organisms, which results in massive scarring; the unsatisfactory surface covering and extensive retraction of skin; and the possibility, based upon past experience, that amputation might eventually become necessary.

It seems important to classify dirt-soiled wounds into three groups on the basis of the type of bacterial contamination to which they have been subjected: (1) Those occurring in urban households and machine shops are least contaminated; (2) those sustained in street accidents are more seriously contaminated; and (3) those occuring in suburban or rural surroundings exhibit dangerous contamination of bone and soft parts by the soil of

highly cultivated districts. All of the patients in this series were given prophylactic treatment, consisting of combined gas and tetanus antiserum. It is realized, however, that, in the case of soil-contaminated wounds, it is of the utmost importance to consider the advisability of open treatment. The fate of the patient will depend upon the experience and judgment of the operator who is familiar with both open and closed treatment, and upon his ability to perform a complete débridement. Since the most dangerous anaerobes are saprophytic, the wound should be left open unless the devitalized tissues can be removed completely.

SUMMARY

A series of 150 consecutive compound fractures has been treated by primary suture, partly with and partly without the advantage of the bacteriostatics, a blood bank, and a high-protein diet.

In respect to wound healing, bony union, prompt restoration of function, and the salvaging of extremities, the results have been superior to those obtained by previous methods.

Improved results are attributed, first, to the compression dressing; second, to immediate coverage of the surface defect with skin or a split-skin graft; and third, to immediate or delayed internal hairline reduction, with metallic fixation when indicated.

The hazard of primary suture is greatly reduced by penicillin and the availability of whole blood. Healing by first intention has been more frequent since the adoption of more radical excision of partly or wholly devitalized skin flaps. Temporary removal of the tourniquet has been found to be the only dependable aid in evaluating the vitality of the skin.

A thorough knowledge of and versatility in skin-plastic surgery are important for selection of the optimum covering of the individual skin defect. Preference is given to the approximation of relaxed flaps, whenever possible. Defects caused by relaxing incisions are covered, immediately or later, by split grafts.

Evaluation of the end results of compound fractures is facilitated by photographs of the external wound, made at the time of the usual admission roentgenogram, and repeated two weeks later at the time of the first dressing.

An attempt has been made to evaluate the therapeutic indications of each case on admission and to determine the factors which require immediate treatment. Definitive fracture treatment should frequently be postponed. It is usually advantageous to carry out simultaneously the treatment of shock and a careful débridement, followed immediately by closure of the skin and the application of a compression dressing.

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DISCUSSION

DR. H. EARLE CONWELL, BIRMINGHAM, ALABAMA: It is appropriate that Dr. Davis should present this discussion before a group of specialists. The technique he describes can be used only by surgeons who are thoroughly familiar with it; it is not to be used indiscriminately.

Even though Dr. Davis did not minimize the importance of soft-structure damage, many of these cases, in my opinion, would have responded to skeletal traction and later to some form of plastic procedure to the soft structures. We see cases in which too much internal fixation will bring about non-union and other complications. In certain cases good function may be obtained by the use of traction, as well as by the methods described by Dr. Davis.

The importance of thorough cleansing and débridement cannot be overemphasized; however, conservative débridement should always be carried out. I agree that in certain cases of compound fractures, internal fixation can be carried out primarily, but such cases form a small proportion.

DR. KELLOGG SPEED, CHICAGO, ILLINOIS: It is well known that a preponderating number of compound fractures in this country are cared for by practitioners and surgeons less highly trained than are to be found in this group. Consequently, while admiring Dr. Davis's results, it is my usual habit in a teaching hospital to employ simple means and more balanced skeletal traction to obtain and hold reduction of open fractures, after generous and complete débridement under the best surgical conditions. This is so whether the fracture is of the femur or the phalanx of a finger. In civil life, with the patient under hospital control, primary plating of an open fracture after débridement may succeed; infections will be minimized as the operator's experience progresses; and primary suture may nearly always be attempted, either by flap-shifting methods or by immediate skin-grafting on wounds which are difficult to close, followed by gentle compression dressings, such as Dr. Davis showed us. Also, we know that frequent redressings must be avoided. To expect these results from all operating practitioners is, however, still asking too much of our less intensely trained colleagues.

DR. ARTHUR DAVIS (closing): From long experience with this audience, I am prepared for criticism of a conservative and skeptical quality. I would like to ask, however: "Of what does conservatism consist?" A while ago the word radical was applied to wide incisions for exposure and drainage. Is it not more conservative to depend upon primary closure, predicated upon the conditions set forth in the paper, than to interfere with such bone and soft-parts repair by exposing deep cells to the damaging effects of atmosphere, et cetera?

Prior to 1936 the compound fractures at Hamot Hospital resulted very frequently in delayed union, non-union, prolonged arduous care, sequestration, and amputation. There were no compression dressings, skin plastics, standardized inert metals, skin grafts, sulfonamides, penicillin, or blood transfusions. Each swing of the pendulum finds us in a different mood, with new tools in our hands. This subject has swung between alternations of open and closed treatment for about one hundred and fifty years. The recently acquired knowledge in these fields requires reorientation of these different factors in relation to compound fractures.

The difference between the results in our own Hospital in the last ten years and in the ten years immediately preceding is as the difference between night and day. We do not lose extremities today. We expect union almost as promptly as though the fracture were simple; we convert the compound fracture to a simple one immediately (within a few hours of injury). I do not like to think of what might have happened to the fifty-six tibiae in this series if they had been treated by an open method. We do not plate immediately in all cases. We close the wounds primarily, after a careful débridement. Sometimes such débridement is impossible, because of the sacrifice of tissues vital to the extremity.

The reason for presenting this paper here rather than elsewhere is that this group is equipped to execute the exacting technique required. The goal in terms of prompt callus formation and prompt wound healing seems infinitely worth while. We in Erie, with the evidence of the two decades before us, could not possibly return to any kind of open treatment for the great majority of our compound fractures.

PRIMARY ANTERIOR CONGENITAL DISLOCATION OF THE HIP*

BY H. R. MCCARROLL, M.D., ST. LOUIS, MISSOURI

From Shriners' Hospital for Crippled Children, and Department of Surgery, Washington University School of Medicine, St. Louis

Ryerson, in 1907, first reported a case of primary anterior congenital dislocation of the hip. This apparently stimulated little interest in the subject, however, and a thorough search of the medical literature reveals no further reference to this distinct clinical entity until 1939. The fact that this type of dislocation is more difficult to treat than the more common posterior type was apparently not recognized.

In 1939, a series of ten cases with dislocation of the primary anterior type was reported by McCarroll and Crego. Further study of this condition over a period of twelve years revealed that the anterior dislocation is not so rare as was originally thought. In a series of 111 congenital dislocations of the hip, observed from 1935 to 1945, inclusive, the primary anterior type was encountered in twenty-five hips or 22.5 per cent. of the entire group. The clinical manifestations responsible for the classification of this type of dislocation were thoroughly covered in the author's initial report and will not be repeated. Observation over a period of eight additional years has brought no change in these diagnostic criteria.

FIG. 1

J. M. Primary anterior congenital dislocation of the hip, ten years after massive anterior shelf operation. Patient obtained a fair result, with good motion; one-half inch of shortening and some pain resulted.

A plan of treatment was suggested in the previous report; this consisted of preliminary skeletal traction, followed by attempted closed reduction, and, after closed reduction had failed, by open reduction and the production of a superimposed massive anterior shelf. Every attempt was made to place the femoral head in the acetabulum, although in many instances it was impossible to maintain this reduction even at operation. Of the three hips in which the femoral head could be held in the acetabulum at the time of operation, recurrent dislocation into a true anterior position followed very early in two. The massive anterior shelf, extending from the posterior margin of the acetabulum to the anterior superior spine, was used, therefore, in order to afford stability and a weight-bearing surface for the femoral head, whether it was left in an anterior position at the time of open reduction or returned to this position after operation. Twelve operations of this type were performed, and the patients have been followed sufficiently long for their results to be evaluated with some measure of accuracy. This follow-up study varies from two to ten years, with an average of 5.8 years, for the twelve hips (Table I). Results from this surgical procedure were stated to be entirely satisfactory at the time of the initial report. Additional time, however, has proved the fallacy of this statement. Most of these hips have subsequently shown shortening of from one-quarter to three-quarters of an inch; and the patients have experienced limp, positive Trendelenburg sign, and pain, apparently from secondary traumatic arthritis (Figs. 1, 2, 3, and 4). In this series of twelve hips, five are now classified as fair and six as poor.

The additional hip (Fig. 5), classified as good, remained well seated in the acetabulum

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.

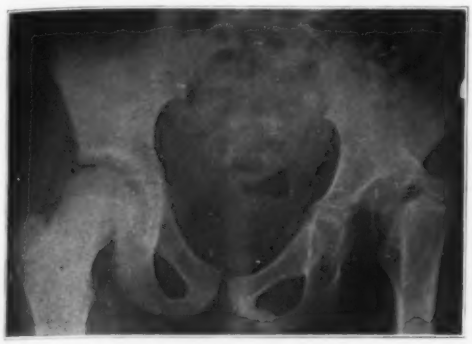

FIG. 2

FIG. 3

Fig. 2: F. T. Primary anterior congenital dislocation of the hip, six years after massive anterior shelf operation. The result was poor, with one and one-half inches of shortening, and some pain; motion was good. The shelf is undoubtedly still functioning.

Fig. 3: W. D. Primary anterior congenital dislocation of the hip, ten years after massive anterior shelf operation. The result was fair, with good motion, one-quarter inch of shortening, and no pain. The shelf still functions, but there has been no attempt to establish a smooth, rounded, weight-bearing surface.

FIG. 4

FIG. 5

Fig. 4: V. W. From a roentgenographic standpoint, this represents the best end result in the group treated by massive anterior shelf operation, but the patient was followed for only three years. The result is classed as fair, with fair motion, shortening of three-quarters of an inch, and no pain. The femoral head appears to be in the acetabulum, but is actually in an anterior position.

Fig. 5: A. B. (case 8 in the original report). This shows the one hip of the entire group, treated by massive anterior shelf operation, which remained seated in the acetabulum. The shelf has now entirely disappeared, ten years later. The result is classed as good, with good motion, no shortening, and no pain.

after open reduction and did not become redislocated, as did the others; the massive anterior shelf was gradually absorbed over a period of several years. A shelf will persist only when it is in active use, which was obviously not true in this instance. At the time of the initial report, it was felt that attempted closed reduction would invariably fail in this type of hip. It was also felt that recurrent anterior dislocation would follow open reduction, even though in this one hip (listed as Case 8[1]), reduction was still present. In spite of this, simple closed reduction has been attempted in each case as the initial procedure, and it has since proved successful in five hips (Figs. 6-A and 6-B) or 20 per cent. of the entire group. These five cases have now been followed for an average of 2.8 years. Their results are classified as good at this time, and some of them could easily be considered normal hips. Why these five hips of the typical primary anterior type should have responded to closed reduction, while others of the same clinical type failed, is not clear. It may, however, be due to the fact that the anterior rim of the acetabulum was not so defective in these five cases as in the others. The satisfactory results obtained in these cases raise the question as to whether or not the original clinical classification was correct; yet each patient showed the characteristics typical of the primary anterior type.

At the time the massive anterior shelf was being used, five cases were treated by

acetabular reconstruction. Reduction could be accomplished in these hips, and the operation merely changed the angle of the superior rim of the acetabulum, in order to afford a shelf or ledge of bone directly above. This was used in those instances in which the hip

FIG. 6-A

FIG. 6-B

Fig. 6-A: J. C. Primary anterior congenital dislocation of the hip in a child, two years of age. Treatment consisted of preliminary skeletal traction and closed reduction. (Supracondylar derotational osteotomy was performed as the final step in the treatment of all cases included in this report.)

Fig. 6-B: The same hip, four years after treatment. The result was classed as good, with normal motion, no shortening, and no pain. Treatment by closed reduction in this manner succeeded in only 20 per cent. of the cases.

FIG. 7-A

FIG. 7-B

Fig. 7-A: B. P. Untreated primary anterior congenital dislocation of the hip in a child, six years of age. Treatment consisted of skeletal traction; open reduction; and superior acetabular reconstruction, with an attempt to curve the shelf anteriorly and inferiorly to produce an anterior ledge.

Fig. 7-B: The same hip after five years. The result was classed as fair, since the hip remained reduced and stable, yet the motion was only fair and some pain was present.

FIG. 8-A

FIG. 8-B

Fig. 8-A: P. H. Untreated primary anterior congenital dislocation of the hip in a child, three years of age. Treatment consisted of skeletal traction, open reduction, and acetabular reconstruction superiorly.

Fig. 8-B: The same hip, three years later. The result is classed as fair. Even though the hip is still stable, has normal motion, and no pain, the femoral head is not well seated in the acetabulum. It tends to ride outward and anteriorly, and permanent reduction may not yet be assured.

seemed a little more stable at the time of open reduction. In two instances, however, an attempt was made to curve the shelf anteriorly and downward to form a partial curved ledge in front of the femoral head (Figs. 7-A and 7-B). This was difficult and unsatisfactory, because of an insufficient amount of bone at this point.

These five cases have now been followed for an average of 3.6 years. Only one hip can be rated as good at this time. Three are classified as fair and one as poor. The poor result is in a child who was seven years of age at the time of operation. After two years the hip shows very little motion; functionally it is poor; and there is still some question as to whether or not reduction will be permanent. Of the group classified as fair, pain is present in one after five years (Figs. 7-A and 7-B) and two are questionable from the standpoint of permanent reduction. The hips show some tendency to slip forward in the acetabula (Figs. 8-A and 8-B), even though they have not actually become redislocated. Even if results in all five cases of acetabular reconstruction were satisfactory, this method could still not be relied upon as a satisfactory means of treatment. The twelve hips in which a massive anterior shelf was formed also had the equivalent of a superior acetabular reconstruction, since the shelf was started at the posterior rim of the acetabulum. Reduction was still possible in only one hip; this reduction was maintained.

In one patient (Figs. 10-A, 10-B, and 10-C), several attempts at closed reduction were unsuccessful, and the femoral head could not be held in the acetabulum even at open operation. The acetabulum in this case was deepened by removal of its articular cartilage and considerable bone from its depth. In this way an anterior rim or ledge was developed in the acetabulum, and the head remained seated. The articular cartilage of the femoral head was placed in direct contact with the cancellous bone of the acetabular bed, without the use of an autogenous or foreign arthroplasty medium. After four years, the result in this hip can be classified as fair. The hip has not become redislocated, although the femoral head is riding at the outer edge of the acetabulum and, from a roentgenographic standpoint, does not appear very stable. The motion in this hip is fair, and already there is evidence of progressive traumatic arthritis in the joint. Its appearance, even at the time of operation, did not justify another attempt at reduction by the same method.

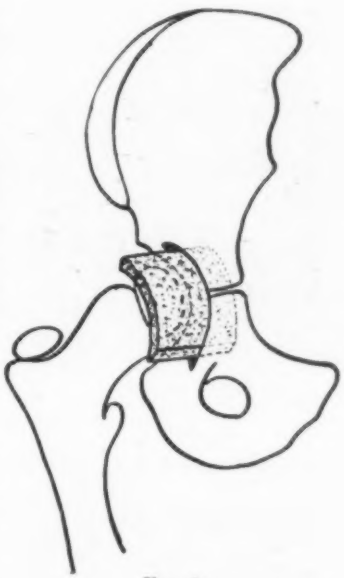

FIG. 9

Diagram showing the type and location of free graft, used in the anterior buttress operation. The graft is driven intracapsularly into the anterior rim of the acetabulum, allowing it to project laterally in front of the head and neck of the femur.

It has always seemed wise in the management of these hips to maintain the architecture of the two articular surfaces, if at all possible. This accounts for our persistent effort in most instances to avoid the use of some form of arthroplasty. Following this criterion, still another form of surgical reconstruction has been attempted,—namely, the use of the anterior buttress. The basic underlying anomaly in the primary anterior congenital dislocation is a defect in the anterior acetabular rim. Attempts were made to repair this in some of the earlier operations, in exactly the same way that the superior rim of the acetabulum is reconstructed. This was never successful, however, because of an insufficient amount of bone along the anterior portion of the acetabulum. One final attempt has been made to accomplish this by means of a large free graft, removed from the wing of the ilium, and which, for lack of a better term, is called the anterior buttress (Fig. 9). This large graft is curved slightly in its lateral plane and driven into a wedge, cut along the anterior rim of the acetabulum. The mass of the graft is allowed to project laterally, directly in front of the femoral head. This was first

FIG. 10-A

FIG. 10-B

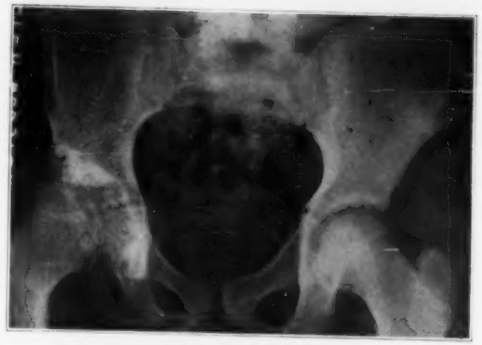

FIG. 10-C

Fig. 10-A: W. W. Untreated primary anterior congenital dislocation of the hip in a child, seven and one-half years of age. Attempts at closed reduction failed three times.

Fig. 10-B: The same hip, three years later, after the third attempt at closed reduction had failed. At this time open reduction and deepening of the acetabulum were performed.

Fig. 10-C: Four years after operation, the result is classed as only fair. Motion is fair, there is no pain, and the hip remains stable; yet the femoral head is riding near the outer rim of the acetabulum, and considerable traumatic arthritis is apparent.

FIG. 11-A

FIG. 11-B

FIG. 12

Fig. 11-A: S. S. Primary anterior congenital dislocation of the hip, eight years after massive anterior shelf operation. The result is classed as poor because of pain, limp, and one-half inch of shortening. Open reduction and anterior buttress operation were performed at this time.

Fig. 11-B: Fifteen months after anterior buttress operation, the result is classed as fair. Reduction has been maintained; there is good motion; and no shortening, pain, or limp are present. The femoral head is not seated deeply in the acetabulum, however, and the superior acetabular rim appears questionable. The anterior buttress can be seen, and has prevented a recurrent anterior dislocation. The original anterior shelf is now disappearing, owing to lack of use.

Fig. 12: L. B. Primary anterior congenital dislocation of the hip, as seen fifteen months after anterior buttress operation and simultaneous superior acetabular reconstruction. The anterior buttress can be seen, a portion of it being attached to the acetabulum. This has, at least until now, prevented a recurrent anterior dislocation. The femoral head is riding far out of the acetabulum, however, and its position does not appear very secure. The result is classed as fair.

TABLE I

RESULTS IN TWENTY-FIVE HIPS WITH PRIMARY ANTERIOR CONGENITAL DISLOCATION

Treatment	No. of Hips	Average Follow-up (*Years*)	Results		
			Good	Fair	Poor
Massive anterior shelf	12	5.8	1	5	6
Successful closed reduction	5	2.8	5	0	0
Acetabular reconstruction superiorly	5	3.6	1	3	1
Deepening of acetabulum	1	4	0	1	0
Anterior buttress	2	1.3	0	2	0
No treatment	1				

attempted by placing the graft extracapsularly, but it was impossible to hold the graft in position in this manner. Later the graft was placed inside the capsule and the capsule was sutured over it, in order to maintain the correct position. Technically, this is a difficult procedure. The anterior portion of the acetabulum is often too poorly developed to permit a graft of this type to be inserted and to project directly laterally, in front of the femoral head. In these instances the graft is simply laid across the front of the hip joint, with its base overlying the denuded acetabular rim, and anchored inside the joint capsule. At times, it has been very difficult to visualize this graft by roentgenogram. The visualized portion of the graft has at other times shown no apparent connection with the anterior rim of the acetabulum, but appears to lie inside the joint, opposite the femoral head or the femoral neck. Whether or not, therefore, the bone graft actually is attached and holds in the manner intended, is impossible to state in many instances. An operation of this type may serve simply to produce an anterior ledge for the acetabulum by extensive postoperative formation of scar tissue.*

Late end-result studies are not possible on hips treated by the establishment of an anterior buttress, and the method is included only as a preliminary report, to show what is being attempted in this type of hip at the moment. It has been used in two hips of the primary anterior type (Figs. 11-A, 11-B, and 12). It has also been used in three primary posterior dislocations, not included in this series, in which redislocation into an anterior position occurred after treatment. No recurrent dislocations have as yet been encountered after this procedure. In the two primary anterior dislocations included in this series, the results can be classified as fair after fifteen months. In one hip (Figs. 11-A and 11-B) a massive anterior shelf had been constructed eight years previously, and proved unsatisfactory because of pain. A simultaneous superior acetabular reconstruction was performed in the second case (Fig. 12), because of an inadequate superior rim, and this amount of surgery probably accounts for the fact that the residual motion is limited to 60 degrees.

CONCLUSIONS

At present it may be safely stated that no universally satisfactory method has been found for treating the primary anterior dislocation which cannot be corrected by closed reduction. In an attempt to accomplish this without disturbing the architecture of the articular surfaces, the use of the anterior buttress will be given further trial. If this proves unsatisfactory, some type of arthroplasty would seem to be the next logical step.

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* Supracondylar derotational osteotomy was performed as the final step in the treatment of all cases included in this report.

Fig. 12. B. Primary anterior congenital dislocation of the hip, as seen fifteen months after anterior buttress operation and simultaneous superior acetabular reconstruction. The anterior buttress can be seen, a portion of it being attached to the acetabulum. This has, at least until now, prevented a recurrent anterior dislocation. The femoral head is riding far out of the acetabulum, however, and its position does not appear very secure. The result is classed as fair.

RESULTS OF TREATMENT OF IRREDUCIBLE CONGENITAL DISLOCATION OF THE HIP BY ARTHRODESIS *

BY CHARLES J. FRANKEL, M.D., CHARLOTTESVILLE, VIRGINIA

From the Department of Orthopaedic Surgery, University of Virginia Hospital, Charlottesville, and the Shriners' Hospital, St. Louis, Missouri

The choice of a proper palliative procedure for treatment of unilateral, irreducible congenital dislocation of the hip has always been most difficult. In 1940, a study was made, by the author, of the cases treated by shelving, osteotomy, and arthrodesis at the Shriners' Hospital in St. Louis and at the University of Virginia Hospital, and the literature was reviewed [1].

The conclusions reached, based on the study of our cases and the results in cases treated throughout the country, were that, in the treatment of this condition, arthrodesis offered the patient the best prognosis, for relief of pain and improved function. None of the other palliative procedures seemed to assure consistently good end results with freedom from pain. We were of the opinion that a child whose economic status was such as to make it almost certain that he or she would, in later life, be required to earn his or her own living, and whose work probably would not be sedentary, would be able to carry on best with a stiff, but painless, hip.

Fourteen patients in the younger group were treated by arthrodesis. Only eight, however, had adequate follow-up studies. The youngest child was seven years of age and the oldest was fifteen. The average age was twelve. The longest follow-up period was twenty-one years; the shortest was four and one-half years; and the average was fourteen years. Seven of the patients were girls.

PROCEDURE

All of the hips were pulled down as far as possible by preliminary skeletal traction, which was applied for from three to eight weeks prior to surgery.

Four patients had initial extra-articular fusions in which tibial or trochanteric grafts were driven through the head distally and the ilium proximally. In one case a secondary extra-articular fusion was performed. The hips were placed in the best position for fusion, and osteotomies were performed later where it was necessary to provide a better functional position.

Fusion was obtained in two hips by simply denuding the femoral heads and placing them in a trap door in the ilium. In one instance, a flap from the ilium was turned down and driven through the femoral head. The flap was held in place by two Vitallium nails. Another hip was fused simply by the use of a long Smith-Petersen nail, which was driven through the femoral neck and head deep into the thick portion of the ilium.

RESULTS

One of the two hips in which no graft was applied failed to fuse. Later, when a graft was used, solid arthrodesis resulted. All of the hips fused well. The average time required for fusion was two years. In several hips, fusion took place in from eleven to fourteen months, while the others required from thirty-two to thirty-eight months.

Prior to traction and surgery, shortening averaged three and one-fifth inches in the eight cases followed. After arthrodesis, shortening averaged three-quarters of an inch; the average correction was two and two-fifths inches. In one case, an epiphyseal arrest

* Presented at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.

FIG. 1-A

FIG. 1-B

FIG. 1-C

Fig. 1-A: Case 1, B. L. Dislocation of hip. Three inches of shortening present on September 5, 1939.
Fig. 1-B: Hip after treatment for six weeks with forty-six pounds of traction.
Fig. 1-C: January 27, 1943. Arthrodesis was performed with the hip in good position.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 2, D. M. Dislocation of hip with three and one-half inches of shortening present on June 2, 1931.
Fig. 2-B: Hip after traction of thirty pounds for twenty-five days.
Fig. 2-C: March 29, 1938. Seven years after first attempt at arthrodesis and osteotomy.

has been performed with no apparent change in the amount of shortening, which, five years after the arrest, is still one and one-half inches.

Our results were tabulated according to a modified standard set up by Galeazzi's clinic and used by Steindler in his report in 1935. All of the patients to date show good results: Their shortening and limp are slight; none have pain; and fatigue is mild in three cases. None of the patients have arthritic complaints, and none consider the stiff hip a major disability.

CASE REPORTS

CASE 1. B. L., a twelve-year-old white girl, had three inches of shortening. Forty-six pounds of traction was applied for six weeks, and then a shelf operation was performed which failed. One month later, fifty pounds of traction was applied for thirty days. This was followed by an extra-articular arthrodesis with a tibial graft. The hip was immobilized for eight months in a hip spica. The end results were three-quarters of an inch of shortening and no complications from traction.

CASE 2. D. M., a fourteen-year-old white girl, had three and one-half inches of shortening. Thirty pounds of skeletal traction was applied for twenty-five days, followed by an intra-articular arthrodesis by simply denuding the femur and acetabulum of cartilage. Immobilization was carried out for eight months, but there was no evidence of arthrodesis. The patient was sent home. She returned in six years, and a subtrochanteric osteotomy was performed. Arthrodesis occurred after six months of immobilization. The end results were five-eighths of an inch of shortening, no pain, and no complications from the pin.

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3, I. C. Dislocation of hip. Three inches of shortening present on May 29, 1936.
Fig. 3-B: Arthrodesis followed three weeks of fifty-pound traction. Subtrochanteric osteotomy was performed to improve position. Results on January 11, 1939.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4, L. C. Dislocation of hip and three inches of shortening present on May 19, 1926.
Fig. 4-B: Arthrodesis three years after grafting.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5, L. M. Dislocation of hip with three and one-half inches of shortening present on November 6, 1925.

Fig. 5-B: Four years after arthrodesis.

Fig. 6-A: Case 6, P. O. Dislocation of hip with three inches of shortening present on September 5, 1939.

Fig. 6-B: Hip after treatment for six weeks with forty pounds of traction.

Fig. 6-C: Four years after osteotomy and arthrodesis.

FIG. 6-A

FIG. 6-B

FIG. 6-C

CASE 3. I. C., a fourteen-year-old white girl, had three inches of shortening. Fifty pounds of traction was applied for three weeks. Intra-articular arthrodesis was done; but simple denuding of the head and acetabulum was unsuccessful. This was followed, seventeen months later, by an extra-articular arthrodesis with a tibial graft and a subtrochanteric osteotomy. The hip was immobilized for eight months. The end result was an excellent fusion and a painless hip. One-half inch of shortening remained; there were no complications from the pin.

CASE 4. L. C., a fifteen-year-old white girl, had three inches of shortening. Seventy pounds of traction was applied for sixty days, followed by an extra-articular arthrodesis with a trochanteric graft. The hip was immobilized for eight months. Good fusion and a painless hip resulted. There was slight fatigue, and three-quarters of an inch of shortening remained. There were no complications from the pin.

CASE 5. L. M., a thirteen-year-old white girl, had three and one-half inches of shortening. She was

FIG. 7-A

FIG. 7-B

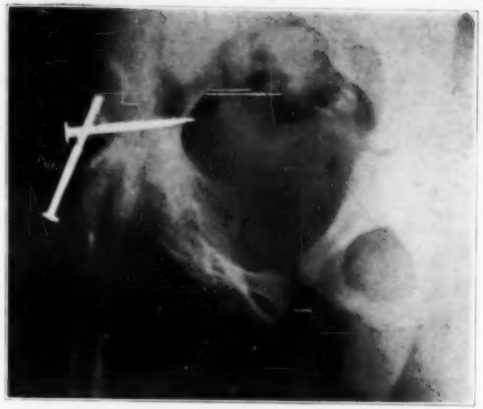

FIG. 7-C

Fig. 7-A: Case 7, E. C. Dislocation of hip and three inches of shortening.
Fig. 7-B: After treatment for three weeks with thirty pounds of traction.
Fig. 7-C: Two years after arthrodesis.

Fig. 8-A

FIG. 8-B

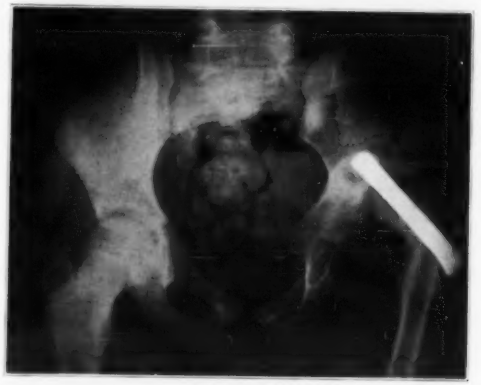

FIG. 8-C

Fig. 8-A: Case 8, P. L. Dislocation of hip and three and one-half inches of shortening.
Fig. 8-B: After treatment for three weeks with traction of forty pounds.
Fig. 8-C: One year after arthrodesis.

treated by fifty pounds of traction for thirty days, followed by simple extra-articular fusion. The hip was immobilized for eight months. The result was good fusion with three-quarters of an inch of shortening and no pain. No complications from the pin occurred.

CASE 6. P. O., a thirteen-year-old white girl, had three inches of shortening. Forty pounds of traction was applied for six weeks, followed by extra-articular application of a massive tibial graft. After immobilization for six months, subtrochanteric osteotomy was done to improve the position of the hip. Immobilization for ten weeks followed. Good fusion resulted. There was one inch of shortening, but there were no complications from the pin.

CASE 7. E. C., an eight-year-old colored girl with three inches of shortening, was treated by thirty pounds of traction for three weeks. This was followed by application of an iliac extra-articular graft and Vitallium nails. The hip was immobilized for six months. Fusion took place in one year. The end results were good fusion and a painless hip; one inch of shortening remained. No complication from the pin occurred.

CASE 8. P. L., an eleven-year-old white boy, had three and one-half inches of shortening. He was treated by application of forty pounds of traction for three weeks, followed by arthrodesis with a four-inch Smith-Petersen nail, which was driven through the neck and head of the femur into the ilium. The boy was immobilized in a cast for four months. Clinical union occurred in one year. A painless hip, three-quarters of an inch of shortening, and good fusion resulted. No complications occurred from the pin.

Many of the early cases were treated by Dr. Leroy Abbott. Kirschner wires and later bicycle spokes were used for skeletal traction and were placed through the lower third of the femur. No sign of nerve palsy or any circulatory difficulty developed in any of the cases. In two cases, not included in this series, small ring sequestra developed about the wires. These were thought to be due either to the high-speed electric drill used or to the side-to-side movement of the wire. This complication has been eliminated by the use of a slower-speed drill and threaded wires. All of the children complained of pain after a week or two of traction, but mild sedation was adequate to carry them through the treatment. No accurate check was made of changes in pulse rate. Countertraction was obtained by extremely high elevation of the foot of the bed.

CONCLUSIONS

Arthrodesis, in cases of patients with unilateral, irreducible congenital dislocation, assures the best results as far as pain and fatigue are concerned. The operation should be limited to patients of the lower economic level. Sociologists estimate that a child has one chance in twelve of rising from a low social-economic level to the so-called middle-class level. If such a child must expect to earn his or her living through manual labor, a painless hip is almost a necessity.

In the small series of cases presented, uniformly good results were obtained by arthrodesis. Other clinics have also reported similar results in their small series of cases [2].

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FOLLOW-UP STUDY OF THE EARLY TREATMENT OF CONGENITAL DISLOCATION OF THE HIP *

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The early treatment of congenital dislocation of the hip in this Clinic is based on the premise that forceful manipulation and reduction, with prolonged plaster immobilization, constitute unsound treatment. In the authors' experience, this method, formerly known as the "bloodless reduction", has proved to be unjustified.

Our results from the use of forceful manipulation have been discouraging from the standpoint both of immediate effect and of long-term observation. Experiences here closely parallel the results reported by Gill in a recent follow-up study of this method of treatment of congenital dislocation of the hip.

The groundwork for our present management of congenital dislocation of the hip was laid prior to 1933, and the preliminary work has already been reported by Crego and by McCarroll and Crego. These reports discussed the objections to "bloodless reduction"; therefore, further discussion will not be offered in the present follow-up study. In none of the present series of cases has it been found necessary or even advisable to resort to forcible manipulation and immobilization in the frog position, in order to obtain a satisfactory result.

The present analysis deals with follow-up observations in those cases treated initially before the children had passed their seventh year. Four of the total number were treated first between the ages of one and two years; four were treated initially between the ages of six and seven years; and seventy were treated first between the ages of two and six years. The correlation of end results with respect to age at the time of initial treatment is shown in Graph I, and from this it can readily be seen that the optimum age for treatment lies between two and five years. The greatest percentage of normal end results was obtained in that group treated first at two years of age.

The cases reported have been followed for a minimum of one year and a maximum of fifteen years after the completion of treatment. In approximately 50 per cent. of the total number of hips, the follow-up study has been continued for six years or more.

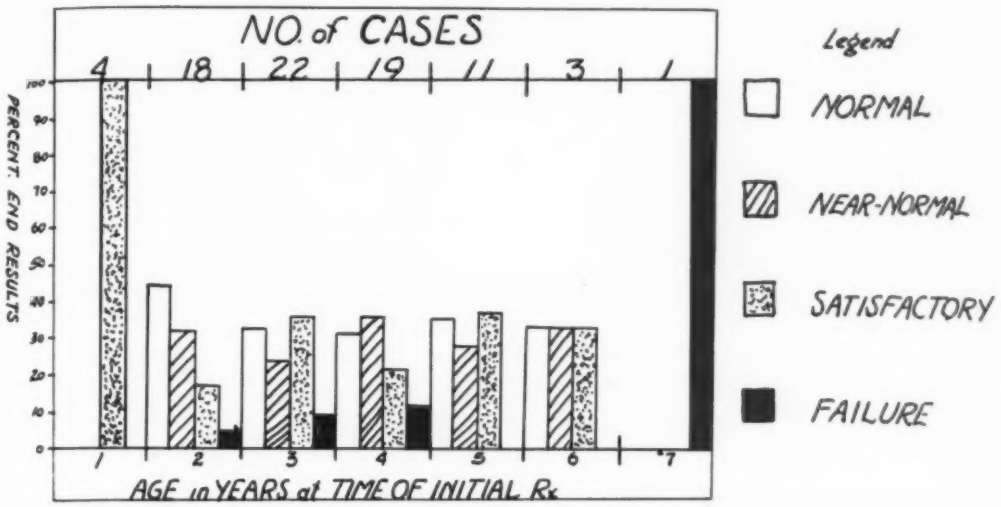
Since 1933, a total of ninety-three dislocations of the hip, within the age group reported, have been seen. Of these, sixty-one are classified as primary posterior dislocations, seventeen as primary upward luxations or subluxations, and fifteen as primary anterior dislocations. The criteria for such a classification have already been presented in detail by McCarroll and Crego.

The present analysis deals with those hips classified as having primary posterior dislocation, primary upward luxation, or subluxation, and involves seventy-eight hips in fifty-two patients. The fifteen primary anterior dislocations are being analyzed in a separate report by McCarroll, which appears in this issue of *The Journal*, and will not be included here.

METHOD OF TREATMENT

Treatment of congenital dislocation of the hip is directed toward restoring the hip joint to a state as nearly normal as is possible, both functionally and anatomically (structurally). Sound treatment requires, first, that all the factors contributing to the abnormality of the hip joint be recognized, and second, that these factors be made as nearly normal as possible.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.



GRAPH I

Shows relationship of age at initial treatment to end result.

In analyzing a hip for treatment, the various factors to be considered, which may be present at the time of initial examination or may be observed during treatment, are:

1. The dislocation itself;
2. Anomalies of the head and neck of the femur;
3. Anomalies of the capsule;
4. Anomalies of the acetabulum.

We believe that the logical treatment of congenital dislocation of the hip requires that any abnormality which presents itself, and prevents either reduction initially or maintenance of the reduction, should be corrected when the necessity first arises.

The Dislocation Itself

In seventy-one of the seventy-eight hips, the dislocations were complete,—that is, the head of the femur lay completely outside the acetabulum in either a posterior or an

FIG. 1

FIG. 2

Fig. 1: Bilateral dislocation in which the right hip is incompletely or partially dislocated; the left is completely dislocated.

Fig. 2: Showing clinical appearance in different types of dislocations.
A: Bilateral primary anterior dislocation.
B: Bilateral primary posterior dislocation. *C:* Bilateral upward luxation.

FIG. 3

FIG. 4

Fig. 3: Congenital partial absence of femoral neck. Such anomalies prevent maintenance of reduction by any means.

Fig. 4: Showing method of correcting femoral torsion by supracondylar osteotomy. This procedure is seldom done on both sides simultaneously.

FIG. 5-A

FIG. 5-B

Method of determining presence of femoral torsion.

Fig. 5-A: Anteroposterior view of pelvis, with both knees in neutral position. Torsion is present bilaterally.

Fig. 5-B: Both knees are in 70 degrees of internal rotation, showing normal angles of femoral neck.

Fig. 5-C: Showing result five years later. Each hip was treated by skeletal traction, followed by derotational osteotomy to compensate for femoral torsion. Treatment was started at two years of age. The left hip was treated completely before treatment was started on the right hip. The results were graded as normal bilaterally, five years after treatment was begun.

FIG. 5-C

upward position. The other seven were incomplete dislocations or subluxations, in which the head of the femur lay outside the socket, with partial upward displacement (Fig. 1).

In order to bring the head of the femur from its position of dislocation or subluxation to a position where it could be placed into the acetabulum without violent force, two methods were used,—manipulation and traction. Manipulation, as used in this Clinic, means that, with no more force than is required to demonstrate telescoping, the head of the femur is brought within the acetabular fossa. Traction, either skeletal or skin (if sufficient), was used as a preliminary to reduction in all cases which would require more than the amount of force of manipulation to place the head within the acetabulum. Forcible manipulation under anaesthesia has not been used in any of these cases.

When traction is used to pull the head of the femur down opposite the acetabulum,

FIG. 6-A

FIG. 6-B

Roentgenographic appearance, eight years after beginning of treatment (Fig. 6-B), in a case classified as normal, right, and failure, left. Treatment was started at four years of age in this case of bilateral posterior dislocation. The right hip was treated by skeletal traction after tenotomy of the hip flexors and adductors, followed by open reduction. Femoral torsion was not present at open reduction. The left hip was treated by skeletal traction, and stable reduction was achieved. Torsion was present but was purposely not corrected, to demonstrate that it will not correct itself spontaneously. The left hip was redislocated to an anterior position two years later, because of failure to correct the torsion of the femoral neck.

the head of the femur should be brought into the proper position within a two-week period. Traction is continued, the position obtained being maintained for a total of four weeks. Following this, and usually with the use of an anaesthetic, the head of the femur can easily be placed into the acetabulum by internal rotation and abduction of the thigh. In this position plaster is applied, and the reduction is maintained in plaster for three months before further treatment, if indicated, is carried out.

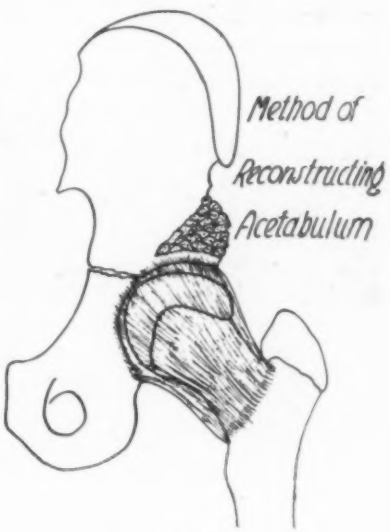


FIG. 7

Diagrammatic sketch shows the method of acetabular reconstruction used in this series.

Five of the seven subluxations were reduced by simple manipulation without an anaesthetic, and did not require preliminary skeletal traction. In two of the five, reduction was achieved spontaneously by the hips being placed in wide abduction and internal rotation. These two required that femoral torsion be corrected, in order to maintain reduction. In the other three, spontaneous reduction occurred during treatment for complete dislocation in the opposite hip, and the subluxations remained reduced without further treatment. Of the remaining two subluxations, preliminary skeletal traction was required to bring the head of the femur opposite the acetabulum, preparatory to reduction.

The seventy-one complete dislocations required preliminary traction to bring the head of the femur into a position where it could be placed into the acetabulum. Usually skeletal traction was required, since in only twelve cases could satisfactory pull be applied by means of adhesive skin traction.

Gill reported that in thirty (approximately 9 per cent.) of his cases, the hips were irreducible by bloodless reduction in patients under four years of age. In the authors' series it was possible in every instance to bring the head of the femur into a satisfactory relationship with the acetabulum, in order to permit reduction; but stable seating of the hip joint after traction, as the *only initial* treatment, was possible in only about 55 per cent. of the total cases.

This observation indicates that correcting the malposition of the head of the femur alone resulted in stable seating of the joint in slightly more than one-half of the total hips treated. For many of this number, correction of other abnormalities was required to *main-*

tain stable reduction. In only eleven of this series, or 14 per cent., was traction or manipulation alone sufficient to maintain stable reduction.

In addition to correction of the malposition of the femoral head, it was necessary to correct associated abnormalities, in about 85 per cent. of the total hips treated, before a stable reduction was effected by the initial treatment.

In addition to the *degree* of dislocation, we take into consideration the *type* of dislocation, and have found, as reported by McCarroll and Crego, that primary posterior dislocation and upward luxations and subluxations are more amenable to treatment than are primary anterior dislocations. This is of value from a prognostic standpoint (Fig. 2).

Anomalies of the Head and Neck

Certain anomalies, such as absence or partial absence of the neck of the femur, prevent maintenance of reduction by any form of treatment. The so-called "reptilian" hips, mentioned by Stewart, and those with absence of both the head and neck, are not amenable to reduction. In these instances a pelvic-support type of osteotomy of the femur is needed. This particular problem was not encountered in the present series (Fig. 3).

Femoral torsion, in which the head and neck of the femur are angulated forward to the normal position with relation to the coronal plane of the femur, was observed in seventy-one cases. This anomaly, if uncorrected, results in redislocation of the hip, with the head resting in an anterior position. The hip joint is not restored anatomically unless torsion is corrected, and experience has shown that the torsion does not correct itself[2].

FIG. 8-A

FIG. 8-B

Roentgenographic appearance of results classified as satisfactory. Posterior dislocation is present bilaterally. The left hip was treated at three and one-half years of age; the right hip was treated at five years of age. Treatment in both instances consisted of skeletal traction, followed by correction of femoral torsion. Fig. 8-B shows appearance three and one-half years after treatment was begun.

FIG. 9-A

FIG. 9-B

Roentgenographic appearance, seven years after beginning of treatment, of results classified as normal, right, and near normal, left. This was a bilateral posterior dislocation. Treatment was started at three years of age and each hip was treated separately. Treatment consisted of preliminary skeletal traction, followed by correction of femoral torsion on both sides.

FIG. 10-A

FIG. 10-B

M-66. Bilateral posterior dislocation. Treatment was begun at two and one-half years of age. The right hip was treated by skeletal traction, but became redislocated six months later; it was subsequently treated by acetabular reconstruction and derotational osteotomy. The left hip was treated by skeletal traction only.

The result was graded as normal bilaterally, eleven years after the beginning of treatment.

FIG. 11-A

FIG. 11-B

K-180. Bilateral posterior dislocation. Treatment was begun at three years of age. The right hip, treated first, required skeletal traction only. The left hip was treated by preliminary skeletal traction and derotational osteotomy.

Results were graded as normal bilaterally, twelve years after beginning of treatment.

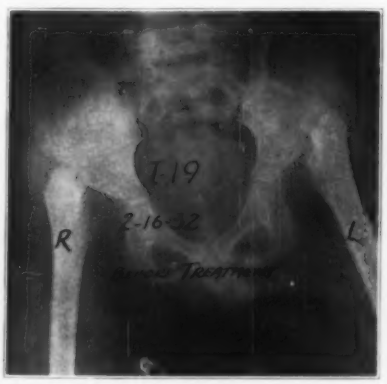


FIG. 12-A

FIG. 12-B

I-19. Treatment was begun at four years of age. The right hip was treated by tenotomy of the hip flexors and adductors, with skin traction, followed by open reduction and acetabular reconstruction. The left hip was treated by tenotomy of the hip flexors and adductors, with skeletal traction and derotational osteotomy; it became redislocated three years later, and was again treated by skeletal traction and acetabular reconstruction.

Eight years after the beginning of treatment, the results were graded as near normal, right, and normal, left.

TABLE I

RESULTS IN HIPS REQUIRING ACETABULAR RECONSTRUCTION

Results	Age at Time of Acetabular Reconstruction						Total
	1 Year	2 Years	3 Years	4 Years	5 Years	6 to 15 Years	
Normal	0	1	2	1	1	4	9
Near normal	0	1	1	2	3	0	7
Satisfactory	0	1	5	6	1	3	16
Failures*	1	1	2	2	1	1	8
Totals	1	4	10	11	6	8	40

* In 3 of these cases a secondary acetabular reconstruction was done, with satisfactory results. The first reconstructions in these patients were done at 1, 4, and 5 years of age; secondary reconstructions were done at 4, 5, and 8 years of age, respectively.

Surgical correction by means of femoral osteotomy has been used to compensate for torsion sufficient to interfere with the maintenance of stable reduction of the hip (Fig. 4).

Before treatment, roentgenograms have been taken routinely of the pelvis with both femora in neutral position, and with both femora internally rotated. In this manner femoral torsion can be demonstrated easily, as shown in Figures 5-A, 5-B, and 5-C. In seventy-one hips of the present series, definite femoral torsion was seen; in five no torsion was present; two were borderline. A total of sixty-seven derotational osteotomies were done in the

TABLE II

FINAL RESULTS AFTER TREATMENT

Type of Dislocation	Successful Results (92 Per cent.)			Unsuccessful Results (8 Per cent.)	Totals
	Normal	Near Normal	Satisfactory	Failures	
Primary posterior dislocation	19	18	20	4	61
Primary upward luxation or subluxation	7	4	4	2	17
Totals	26 (33%)	22 (28%)	24 (31%)	6 (8%)	78

FIG. 13-A

FIG. 13-B

N-62. Bilateral posterior dislocation. Treatment was begun at three years of age. Both hips were treated by preliminary skeletal traction, followed by derotational osteotomy. Nine years after treatment was begun, the results were graded as near normal, right, and normal, left.

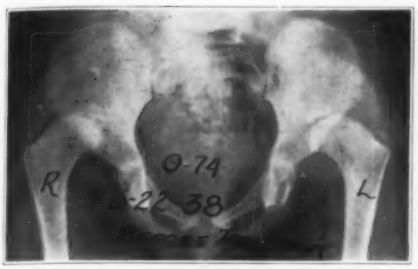


FIG. 14-A

FIG. 14-B

O-74. Treatment was begun at two years of age, and consisted of skeletal traction and correction of bilateral torsion. The right hip became subluxated five years later, and acetabular reconstruction was performed. The results were finally graded as normal bilaterally, seven years after the beginning of treatment.

FIG. 15-A

FIG. 15-B

FIG. 15-C

H-241. Patient originally had bilateral posterior dislocation. He was treated on the right by skeletal traction, open reduction, and acetabular reconstruction; on the left, by skeletal traction and derotational osteotomy. Torsion on the right was purposely not corrected, to demonstrate that torsion does not correct itself. Five years after treatment the right hip was redislocated anteriorly, and the result was classified a failure. The left hip was classified as near normal. Since this present report was compiled, the patient has been seen again. At the present time both hips have redislocated, resulting in bilateral failure; this demonstrates that those cases which have not reached normal classification must be followed and treated, when indicated.

This failure will alter the results of treatment by increasing the number of failures by one and decreasing the number of near normals by one (Table II).

seventy-one hips showing torsion. Five of these osteotomies were done for the second time, because of incomplete correction of torsion by the first osteotomy.

After skeletal traction, closed reduction, and plaster immobilization in a position of reduction (abduction and internal rotation of the thigh) for three months, torsion is corrected by supracondylar osteotomy of the femur. Plaster fixation is maintained, with

FIG. 16-A FIG. 16-B

N-34. Treatment, begun at three years of age, consisted of skeletal traction and derotational osteotomy. The result was graded as near normal, twelve years later. Fig. 16-B shows results one and one-half years after treatment; Fig. 16-C demonstrates improvement of appearance ten years later.

FIG. 16-C

the upper portion of the femur held in internal rotation, by incorporating a threaded wire through the bone just above the osteotomy site, while the knee and leg are rotated externally to neutral position. This position is held for two months longer, to allow the osteotomy to heal.

The effect of failure to correct torsion has already been reported. It is demonstrated in Figures 6-A and 6-B, in which torsion was purposely left uncorrected after an initial stable reduction of the hip, with the result that the head of the femur became redislocated into an anterior position.

Anomalies of the Capsule

It has been demonstrated repeatedly, as mentioned by Stewart, that the classic hourglass constriction, or invaginated fold of the joint capsule, may be interposed between the head of the femur and the acetabular fossa, thereby preventing satisfactory seating of the hip joint. After initial reduction, the head of the femur may stand out from the acetabular socket; yet in many instances, after three months' immobilization in plaster, the femoral head is found to be seated well and reduction is stable. This is probably the result of erosion of a capsular fold, or stretching of a partial constriction, which allows deeper seating of the joint.

In other cases it has been observed that, after initial traction sufficient to pull the head of the femur down opposite the acetabulum, the head can still not be seated into the socket sufficiently to maintain reduction. Open reduction of such dislocations after preliminary traction has revealed the capsular anomaly, and frequently the fossa is found to be filled with firm, fatty tissue and pannus, which hinder satisfactory seating of the head. Excision of the obstructing fold of capsule and the fatty tissue filling the acetabulum is indicated when the femoral head cannot be seated sufficiently to effect clinical stability at the time of reduction.

FIG. 17-A

FIG. 17-B

O-115. Unilateral posterior dislocation. The patient was treated elsewhere at three years of age by manipulation and closed reduction. Redislocation occurred two and one-half years later. Treatment in this Clinic, at five and one-half years of age, consisted of skeletal traction, acetabular reconstruction, and derotational osteotomy. The result was graded as near normal, eight years later. Fig. 17-A shows appearance after reduction by skeletal traction. Original films were lost.

FIG. 18-A

FIG. 18-B

R-92. Unilateral posterior dislocation. Treatment, begun at two years of age, consisted of skeletal traction, acetabular reconstruction, and derotational osteotomy. Result was graded as normal, five years later. (Roentgenograms have been reversed.)

After open reduction of the hip joint has been completed, the hip, in abduction and internal rotation, is immobilized in plaster-of-Paris for three months. After this, femoral torsion is corrected, if indicated. The plaster extends from the lower margin of the rib cage to include the toes on the affected side, and is carried down to the knee on the untreated side.

A total of twenty-five open reductions, for the purpose of relieving these obstructions to stable seating of the hip joint, have been done in this series.

Anomalies of the Acetabulum

Acetabular inadequacy of some degree is encountered in almost every instance of congenital dislocation of the hip. If the acetabulum, although shallow, is adequate to maintain initial reduction, it may eventually develop to the point where a well-deepened socket is formed. Nearly 50 per cent. of the hips studied followed this course.

In some of the hips treated it has been found that, after preliminary skeletal traction sufficient to allow placement of the head of the femur within the acetabulum, the head could not be held there in a stable manner, regardless of the position of the limb. Such hips are examined by fluoroscope; and, if the head of the femur can be placed into the acetabulum, yet in abduction and internal rotation a mild upward thrust of the femoral shaft causes the head to slip out of the socket, operative deepening of the acetabulum is indi-

cated. In these instances, acetabular reconstruction was performed during the initial treatment of the hip.

If, by fluoroscopic examination, the head of the femur could not be placed into the socket and stable reduction be effected, it was felt that open reduction was indicated. If, after excision of the interposed capsule and joint debris at open reduction, the reduction could not be maintained in a stable manner because of an inadequate socket, an acetabular reconstruction was then carried out. The operative deepening of the acetabulum, carried out in this series, has consisted in levering the superior acetabular rim down over the femoral head, and backing up this levered rim with cancellous-bone chips, taken from the wing of the ilium. The reconstruction is done as an extracapsular procedure (Fig. 7).

After acetabular reconstruction, the hip is immobilized in plaster, in a position of abduction and internal rotation, for a period of three months before any further treatment is carried out. After treatment has been completed in all phases, the plaster is removed and the hip is loosened up with the aid of physiotherapy. As soon after removal of the plaster as the patient is comfortable, active weight-bearing is begun. Occasionally a long thigh brace is applied for two or three months, if necessary, to protect a supracondylar osteotomy which is uniting slowly.

A total of forty acetabular reconstructions were required in this series of cases. Three of these were second reconstructions, the first operation having proved inadequate during

FIG. 19-A

FIG. 19-B

O-83. Upward luxation, left; posterior dislocation, right. Treatment was begun at three years of age. The left hip was treated by skeletal traction, acetabular reconstruction, and derotational osteotomy. The right hip was treated by skeletal traction and derotational osteotomy at four years of age. Results were graded as normal, bilaterally, eight years after treatment was begun.

FIG. 20-A

FIG. 20-B

Q-1. Bilateral upward luxation. Treatment was begun at five years of age. The left hip, treated by skeletal traction and derotational osteotomy, became redislocated three months later; it was then treated by skeletal traction and acetabular reconstruction. The right hip was treated by skeletal traction, acetabular reconstruction, and derotational osteotomy. Results were graded as normal bilaterally, six years later.

FIG. 21-A

FIG. 21-B

Q-4. Unilateral upward luxation. Treated first at five years of age by skeletal traction and osteotomy. Redislocation occurred six months later, and treatment was again by skeletal traction and acetabular reconstruction. Results were graded as normal, six years later.

FIG. 22-A

FIG. 22-B

V-6. Bilateral subluxation. Treatment was begun at two years of age. Both hips were treated simultaneously in wide abduction and internal rotation, by immobilization in long leg plasters, fixed by cross bars. Immobilization was continued for six months, and then derotational osteotomies were done (see Fig. 4). Results were graded as near normal, two years later.

the follow-up period. Three of the reconstructions were for recurrent dislocation to an anterior position, and have been termed "anterior buttresses". The anterior-buttress operation is described in McCarroll's report on the treatment of primary anterior dislocation of the hip.

In eight of ten hips classified as having primary upward luxation, acetabular reconstruction was required. One of the others will probably require reconstruction before treatment is completed. The remaining one is classified as normal after a follow-up of nine years; no operative work on the acetabulum is required. Of the seven cases classified as subluxation, acetabular reconstruction has been required in two. Thirty acetabular reconstructions have been required in the sixty-one cases of primary posterior dislocation.

The relatively high number of acetabular operations among the patients with upward luxation is explained by the fact that a notched defect of the superior acetabular rim is constantly present in this type of hip, and reconstruction is usually required before a stable reduction can be effected.

Gill states that acetabular operation should be delayed until the patient is five years of age. Such a requirement has not been met in the present series, and the results of acetabular operations done before five years of age (Table I) are not such as to contraindicate reconstructions prior to this age.

RESULTS OF TREATMENT

The results of treatment for this series of seventy-eight cases are analyzed in Table II. In order to compare the results from the method of treatment used in this series with

TABLE III

RESULTS ACCORDING TO LENGTH OF FOLLOW-UP

Results	1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 to 15 Years	Total
Normal	0	1	0	2	1	3	5	4	3	7	26
Near normal	0	5	2	2	0	3	1	0	2	7	22
Satisfactory	3	7	4	3	3	1	0	0	0	3	24
Failures	0	1	1	0	0	0	1	2	0	1	6
Totals	3	14	7	7	4	7	7	6	5	18	78

TABLE IV

RESULTS FROM MANIPULATION OR PRELIMINARY TRACTION, WITH OR WITHOUT DEROTATION OSTEOTOMY

Normal		Near Normal		Satisfactory		Failures		Total Hips
No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	
As the Initial Treatment								
15	33	11	24	6	14	13	29	45
As the Only Treatment								
15	45	11	33	6	19	1	3	33

the results from Gill's bloodless reduction, the criteria set forth by Gill for classification of the results of treatment have been observed critically. The results are graded according to the following classification:

1. *Normal*

This implies normal function of the hip, normal structural restoration of the joint, and complete freedom from symptoms (Figs. 6-A, 6-B, 9-A, and 9-B). Patients with normal results are considered cured, and require no further treatment. The qualifying factors for this classification are:

(a) Normal acetabular structure, either from developmental progress or from surgical reconstruction;

(b) Normal seating of the hip joint;

(c) Normal development of the femoral head;

(d) Normal femoral neck;

(e) Normal function.

2. *Near Normal*

This group includes those hips in which normal function has been restored, with complete freedom from symptoms after full activity; but roentgenographically, anatomical restoration has not quite reached normal (Figs. 9-A and 9-B). Minimal deficiencies in restoration of the acetabulum, head, or neck, and a little less than normal seating of the hip joint may be present on roentgenographic examination. Full correction of femoral torsion and full clinical stability are required. Most of the patients in this group are improving, and many of the hips are expected to become normal as the follow-up period

increases. Continued observation is required, however, and further treatment may be required in some instances. One patient required acetabular reconstruction seven years after initial reduction, and during most of the period of observation could have been classified as near normal; however, subluxation of the hip appeared after seven years. That hip is now graded as near normal.

3. *Satisfactory* (Figs. 8-A and 8-B)

(a) Anatomical restoration of the acetabulum is deficient by roentgenographic examination.

(b) Reduction of the dislocation is maintained, according to roentgenographic examination.

(c) Clinically, the hip is stable.

(d) Normal function is present, or sufficient function to allow full activity of the hip, with relief of symptoms.

(e) Residual deformities of the head and neck may be present, with roentgenographic evidence of mild arthritic changes in the joint.

In none of those hips treated by preliminary skeletal traction did aseptic necrosis of the femoral head develop following reduction. Residual deformity of the head, comparable to the flattening and broadening observed in Perthes' disease, was not observed. Such deformities have been observed in some hips, treated prior to 1933[1,2] by bloodless reduction.

4. *Failures* (Figs. 6-A and 6-B)

(a) Redislocation or subluxation has occurred.

(b) There is loss of a useful range of motion.

(c) Clinical instability of the hip is present, with symptoms of pain and fatigue.

We consider all those hips having a satisfactory, near normal, or normal classification to show successful results from treatment. A total of 92 per cent. were successful, as compared with 8 per cent. which were total failures (Table II).

In Table III the results are classified according to length of follow-up period. Observation of the increasing number of normal results as the follow-up period increases would indicate that this form of management will produce a greater proportion of normal and near-normal hips in future evaluations. Table III shows that 23 per cent. of the cases have been followed from ten to fifteen years, and that nearly 50 per cent. have been followed for six or more years.

The simplest method used in this series to obtain and maintain initial reduction has been the use of manipulation (as defined) or traction, with correction of femoral torsion when necessary. Those hips treated *initially* in this manner, and those having *only* this form of treatment, are analyzed in Table IV. In the cases in which this method of treatment failed when used initially, further treatment has been employed to correct other abnormalities; and the cases have been reclassified, after treatment was completed, according to the final result from all treatment.

In the present series, a total of twenty-one hips were treated for recurrent dislocation, following initial reduction. In four of the twenty-one, the hips had been treated elsewhere by bloodless reduction and the frog position, but redislocation had occurred when the patients were seen here for the first time. Of the twenty-one hips treated as recurrences after a first attempt at maintaining reduction, in only four has a second redislocation occurred. In three of the four treated for a third time, reduction has been maintained in a stable manner.

SUMMARY AND CONCLUSIONS

Seventy-eight congenital dislocations of the hip are reported, and the results of treatment are tabulated. Classification of the results has been particularly critical, the criteria

set forth by Gill being used as a guide; and an attempt has been made to compare the relative efficiency of the method of management carried out in this Clinic with that of bloodless reduction, characterized by forcible manipulation under anaesthesia and prolonged immobilization in the frog position. Twenty-two normal and near-normal hips are shown in Figures 10-A to 22-B, inclusive.

In comparing the results of treatment by forcible manipulation and prolonged fixation in plaster in the frog position with treatment as carried out in this Clinic, the authors believe that the former method is not sound and that its use is not justified in congenital dislocation of the hip which can be treated before seven years of age.

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THE END RESULTS OF EARLY TREATMENT OF CONGENITAL DISLOCATION OF THE HIP

With an Inquiry into the Factors that Determine the Result*

BY A. BRUCE GILL, M.D., PHILADELPHIA, PENNSYLVANIA

"Congenital dislocation" is not an exact term, inasmuch as it includes not only those dislocations which occur before or during birth, but also those which occur after birth. Furthermore, it does not include those congenital abnormalities of the hip which may never lead to dislocation, but which do prevent the development of a perfect hip joint. The factor common to all these conditions is a prenatal defect in the development of the structures of the hip, best called "congenital dysplasia of the hip".

Five years ago the author read a paper before this Association on the same subject[5]. For this present paper additional cases have been analyzed, the former cases have been reviewed and brought up to the present date as far as possible, and an attempt has been made to discover the factors that determine the end results. The condition known as predislocation of the hip has been studied in the author's cases to learn what relation it has to this subject.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 30, 1947.

GENERAL STATISTICS

Patients treated		289
Bilateral dislocations		78
Hips treated †		367
Female	78.35 per cent.	
Male	21.65 per cent.	
Right hip (single)	41.00 per cent.	
Left hip (single)	59.00 per cent.	
Bilateral	26.9 per cent.	
Bloodless reductions		
By author	193	
By other surgeons	51	
Irreducible by manipulation (before four years of age)	33 (13.75 per cent.)	
Inoperable (before four years of age) because of extreme deformities	14 (5.83 per cent.)	
Reducible by manipulation	80.42 per cent.	
Open operations		
Following bloodless reduction by author	63	
Following bloodless reduction by other surgeons	36	
Without history of preceding reduction	92	

END RESULTS OF BLOODLESS REDUCTION

One hundred and five cases have been selected for study. The dislocations were all reduced by the author, and the cases were followed for a sufficient length of time to determine the end results tabulated here. The cases discarded from this study were judged to have been under observation for an insufficient length of time, even though the dislocations were considered to be satisfactorily reduced when the patients were last seen. In a number of the discarded cases, the patients were last recorded as "cured and discharged". The end results recorded here should be studied in conjunction with those presented in a preceding paper[5]. Furthermore, in order to avoid reprinting of illustrations, reference will be made to some of the illustrations used in previous publications.

Number of hips treated by reduction		105
Open operation subsequent to reduction		52
Without subsequent operation		53
End results in hips treated by reduction without subsequent operation		
Perfect	17 (16.19 per cent. of 105 hips)	
Excellent	11 (10.48 per cent. of 105 hips)	
Satisfactory	15 (14.29 per cent. of 105 hips)	
Failures	10	
	53	

The total number of failures was sixty-two, or 59.05 per cent of 105 hips.

The designation *perfect* means perfect function and perfect anatomy. *Excellent* means perfect function and almost perfect anatomy (Fig. 9-E in preceding paper[5]). *Satisfactory* means perfect function in spite of evident defects in anatomy, such as obliquity of the acetabular roof, flattening of the head, or moderate protrusion of the head beyond the acetabular roof; but without an upward migration of the head, which is the evidence of subluxation. Perfect function means the absence of all symptoms: fatigue, pain, limp, positive Trendelenburg sign. *Failure* means recurrence of luxation or subluxation.

The *perfect* hips have been under observation for the following lengths of time: one for three years; one for six years; two for seven years (bilateral); three for eight years; two for nine years (bilateral); two for ten years (bilateral); one for thirteen years (bilateral,—one perfect, one a failure); two for fourteen years; one for fifteen years; one for eighteen years (bilateral,—one perfect, one a failure); and one for thirty-one years (bilateral,—one perfect, one a failure).

† Many hips are not included in these groups because of insufficient or non-available records.

FIG. 1-A

FIG. 1-B

Fig. 1-A: H. T., a man, aged forty-two years (July 24, 1944), with subluxation of left hip. Patient had a bloodless reduction when two years old; has had increasing pain, fatigue, and disability during the past ten years. Negative Trendelenburg sign. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 1-B: July 23, 1945, one year after shelf (buttress) operation, complete relief from symptoms had occurred. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

FIG. 1-C

FIG. 2

Fig. 1-C: July 23, 1945. Showing freedom of abduction. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 2: D. S., a girl. August 8, 1946, seven years after reduction of bilateral dislocation. (For history see Figs. 18-A, 18-B, 18-C, 18-D, and 18-E[5].)

The time required after reduction for a hip to become perfect has varied greatly. Restoration of normal anatomy may be evident as early as three years, or it may be delayed until the age of puberty. (See Figs. 17-A to 18-E, 4-A to 4-E, and 6-A to 6-E in preceding paper[5].)

The *excellent* hips have been under observation for the following periods of time: one for three years (shows every indication of becoming perfect); two for four years; one for eight years; one for nine years; three for ten years; two for eleven years; and one for eighteen years. Eight of these eleven hips may almost be included in the classification of perfect. There is such slight departure from normal anatomy, it seems improbable that any symptoms would ever arise. Furthermore, it has been observed that some hips which earlier had been classified as excellent eventually became perfect. One of the cases under observation for ten years had become almost perfect three years after reduction, when a true Legg-Perthes disease developed which ruined the perfection of the hip (Figs. 19-A and 19-B[5]). The two cases which were under observation for four years cannot yet be classed as perfect, because insufficient time has passed.

FIG. 3-A

FIG. 3-B

Fig. 3-A: E. W., a girl, aged one year and eleven months (January 27, 1944). Patient had predislocation of left hip and dislocation of right hip. The dislocation was reduced by manipulation. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 3-B: February 2, 1945, one year after bloodless reduction of right hip. Note the rapid development of acetabular roof and moderate dysplasia of epiphysis. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

If eight of the *excellent* cases were added to the seventeen proved *perfect* ones, the percentage of successful end results would be 23.81. If all eleven were added, the percentage would be 26.67.

It is, of course, possible that some of the fifteen *satisfactory* cases may become excellent or perfect, but these results have not been proved. It may safely be stated that, if a hip has not become excellent or perfect at puberty, it should be classed as a failure. If obliquity of the acetabular roof has not been corrected at this time, symptoms will develop in later years, because of instability and because of a chronic traumatic arthritis which is due to the anatomical abnormalities of the structures of the hip joint.

It is of interest to note the time after reduction at which the fifty-two operations were done because of luxation or subluxation: twelve, one year after reduction; nine, two years; nine, three years; three, four years; five, five years; two, six years; two, seven years; two, eight years; and eight, eleven to twenty years after reduction. This indicates that redislocation occurs most frequently during the first three years after reduction. Nature completely lacked the power to resume the delayed or interrupted normal growth of the hip in these cases. In many of the patients operated upon in the later years, Nature was able to accomplish partial restoration of the hip to a varying degree, but the power of growth was never sufficient to produce a perfect hip. Eight patients were symptom-free for from eleven to twenty years (Figs. 14-A through 14-E[5]). The author operated upon one patient, not included in these cases, who had a subluxation and was free of symptoms for thirty years after reduction (Figs. 1-A, 1-B, and 1-C).

Whether a hip becomes perfect after reduction, whether there is a varying degree of growth short of the perfect, or whether there is complete failure in the resumption of development seems to depend upon some innate power of growth in the structures of the hip.

Ninety-nine hips, of patients whose ages were recorded, have been tabulated, to show the relation between the age of the patient at the time of reduction and the end result (Table I).

Of twenty-two hips in which reduction was carried out during the first and second years of life, 22.73 per cent. became perfect and 45.45 per cent. were failures. Of thirty-eight hips in which reduction was done during the third year of life, 21.05 per cent. became perfect and 44.74 per cent. were failures. There is a negligible difference in the percentages

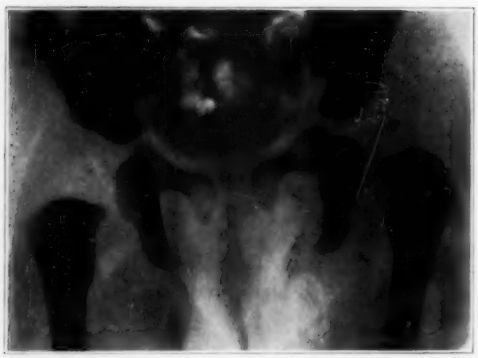

FIG. 4-A

Fig. 4-A: N. D., a girl, aged three months (May 12, 1945). Shows subluxation of left hip. Both femoral heads are visible at this very early age. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

FIG. 4-B

Fig. 4-B: December 3, 1945. Hip has become normal in seven months. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

tabulated in the first two columns. Approximately 35 per cent. of hips treated by reduction during the first three years of life may be expected to become perfect or excellent. After the third year, however, there is a marked decrease in the percentage of successful reductions and a marked increase in the failures. The end of the third year marks a distinct turning point. To this limited extent only do these statistics lend support to the common opinion that the earlier a dislocation can be reduced, the better will be the end result. Successful reductions can be accomplished even after the child is four years of age.

TABLE I

RELATION OF END RESULTS TO AGE OF PATIENT AT REDUCTION

Results	Under 2 Years		Third Year		Fourth Year		Over 4 Years		No. of Hips
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	
Perfect	5	22.73	8	21.05	2	10.53	2	10	17
Excellent	3	13.64	5	13.16	2	10.53	1	5	11
Satisfactory	4	18.18	8	21.05			1	5	13
Failure	10	45.45	17	44.74	15	78.95	16	80	58
Totals	22		38		19		20		99
Perfect and excellent	8	36.37	13	34.21	4	21.06	3	15	

It is generally conceived that the importance of the time factor—that is, the age of the child at the time of reduction—is due to the secondary pathological changes which occur in the anatomy of the hip after dislocation has occurred and which become more marked as time passes. It may be observed, however, that hips which become dislocated as late as the walking age may be more amenable to successful reduction than those which were dislocated at the time of birth or before. The age of the patient may not be the same as the age of the dislocation and, therefore, may not be a definite criterion of the secondary pathological changes in the hip; nor is it necessarily true that the age of the dislocation measures the *degree* and the *importance* of the anatomical changes. Otherwise, all hips of the same age should be similar in the ease of their reduction and in their renewal of growth after reduction. Actually, this is far from the fact.

FIG. 5-A

Fig. 5-A: J. T., a boy, aged two and one-half months (June 5, 1942), with predislocation of right hip. Note absence of calcification of femoral heads. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 5-B: June 21, 1943, one year after beginning of treatment by abduction, the acetabulum is well developed. The epiphysis is just appearing, at fifteen months of age, and is smaller than that of the opposite hip. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 5-C: October 17, 1944. The acetabulum is not yet perfect. Marked aplasia of femoral head is present. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 5-D: January 3, 1947, four and one-half years after treatment was begun, acetabulum is normal. Right femoral head still shows some degree of aplasia.

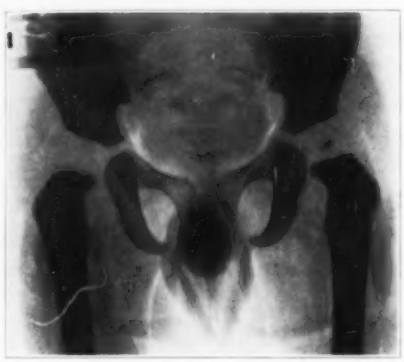

FIG. 5-B

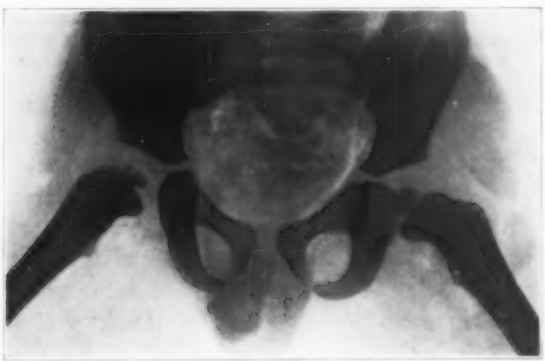

FIG. 5-C

FIG. 5-D

FIG. 5-E

Fig. 5-E: June 13, 1947, five years after treatment was begun. Hip is almost normal, but the femoral head is slightly smaller than normal and protrudes moderately beyond the margin of the acetabulum. This case illustrates delayed growth of both acetabulum and femoral head in a case of predislocation.

If one considers that, in dysplasia of the hip, the acetabular development is weak and defective before dislocation occurs, one can understand that the length of time during which the head remains out of the socket may have an important bearing on resumption of growth of the acetabular roof. In other words, prolonged interruption of growth, occasioned by the absence of normal conjugation of the femur and the pelvis, may so weaken or destroy the natural growth process that it cannot effectively be restored. This conception of the time factor may be much more important than is the relation of this factor to the development of specific secondary pathological alterations in anatomy.

One-third of the hips in which reduction is performed in the first three years of life

become fully or almost normal; two-thirds do not. Some factor, more important than the time factor, is present in the determination of the end results of reduction. This is to be found in the form and the degree of the congenital dysplasia, which is caused by a retardation or by an interruption of normal growth processes. This is well illustrated in Figures 17-A through 18-E[5]. In Case 17 a unilateral dislocation was reduced when the child was three months of age. The femoral epiphyses were visible (smaller in the dislocated femur) at this early age. After reduction, growth was resumed at a rapid rate. At the end of eight months (Fig. 17-C) the hip was almost perfect, and at the end of three years (Fig. 17-D) it was completely normal in anatomy and function.

One might conclude that early reduction of the dislocation was the chief factor in the perfect result, but, in contrast, the case illustrated in Figures 18-A to 18-E shows bilateral dislocations which were not reduced until the child was eighteen months of age. Calcification of the femoral epiphyses was completely absent; the bony acetabula were poorly developed; and there was marked version of the femoral necks. Inspection of the roentgenograms might cause one to think that a perfect result could never be obtained. However, the subsequent films, made after reduction, show a resumption and rapid continuation of growth, which resulted in the development of perfect hips. The final result is shown in Figure 2 in this paper. The resumption and rapid continuation of growth in a dislocated hip, in which reduction was not obtained until the child was two years of age, is illustrated in Figures 3-A and 3-B.

These three cases, in which the dislocations were reduced at three months, eighteen months, and twenty-four months of age, respectively, in all of which the hips were perfect within three years after reduction, indicate that some innate power of growth which has survived delay or interruption is of much greater importance than the time factor in the production of a perfect hip. The other "perfect" hips in this same age group required a longer time, even to the age of puberty, to reach perfection; and, in two-thirds of the hips reduced within the same age period, the results were failures.

A study of predislocation of the hip is of particular value in an observation of the intrinsic and the relative importance of the two factors which determine the end result,—namely, the age at which treatment is begun and the residual and continuing power of normal growth processes.

Inasmuch as 94 per cent. of predislocations may be treated satisfactorily by abduction[6], it would seem at first glance that the time factor is of prime importance in the healing of congenital dysplasia of the hip. This matter will bear analysis, however.

At some time during either embryonal or foetal life, something happens that delays or alters normal morphogenesis of the hip. This etiological factor, whether it be genetic (hereditary) or mechanical, or due to a constitutional or physiological condition of the mother (for it seems possible that in different instances there may be different etiological factors), may exert a very slight or a very profound influence upon the morphological development of the structures of the hip joint. Abundant clinical evidence is available to indicate that many gradations exist between these two extremes. It is generally believed that the severe deformities arise during embryological or early foetal life, because of interruption, distortion, or cessation of normal growth processes. There is some evidence to indicate that the mild deformities may originate during later foetal life, after a normal morphogenesis has been established and is well advanced. It is well known that growing structures may readily be affected by adverse extrinsic conditions, such as mechanical forces and nutritional and biochemical deficiencies, and may suffer retardation and even structural change. Upon restoration of normal conditions, the growth process may continue in the natural way, to produce perfect structures.

If we can reasonably conceive that growth of the hip has been only mildly retarded, we can understand why, in many cases of pre-dislocation and some cases of frank dislocation, rapid and complete recovery may occur under favorable circumstances. If the

FIG. 6-A

FIG. 6-B

Fig. 6-A: J. P., a girl, aged four years (December 8, 1944). Dislocation of left hip and small, shallow, deformed acetabulum are present. Note the acetabulum which is an extension upward of the primary one, with small conical, incompletely calcified head and deformed neck. Two attempts at bloodless reduction failed. (An attempt two years earlier by another surgeon had failed.) The dislocation was reduced February 2, 1945, by open operation. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

Fig. 6-B: October 12, 1945, eight months after open operation, the dislocation remained reduced. The acetabular roof is developing. (*Reproduced, by permission of Thomas Nelson and Sons, from Nelson Loose-Leaf Surgery, 1946.*)

power of growth is more feeble, possibly due to a more prolonged delay or to some constitutional factor, then we can also understand why recovery is more prolonged or why it never becomes complete. The influence of a constitutional factor is illustrated in Case 18[5]. That there is a difference in the rate of recovery after the reduction of dislocations was noted in the early part of this paper and was demonstrated in the paper published in 1943. That a similar difference may occur in predislocations is evident from a study of Figures 4-A to 5-E, inclusive, in this paper. Incomplete recovery is apparent in those cases which have been called satisfactory after reduction and in which a perfect acetabular roof did not develop.

The predislocations probably constitute the largest number of that group in which the damage to the growth process has been slightest, and in which full recovery occurs, not only with a minimum of treatment, but even spontaneously. Scaglietti is of the opinion that dysplasia of the hip is always bilateral in the newborn; that spontaneous healing of predislocation occurs frequently, even beginning during the foetal period; and that spontaneous healing of congenital dislocation may be much more frequent than has been demonstrated to date. If his opinion that dysplasia is always bilateral is correct, it must follow that, in cases of unilateral dislocation, there has been a spontaneous healing of the dysplasia of the opposite hip. The author has observed this condition in a number of his patients. That he has not seen it in all cases may possibly be due to the fact that spontaneous healing had occurred before the child was first examined.

If these statements in regard to predislocations are correct, it would appear possible that the time factor has much less influence upon the recovery of predislocations than it does in dislocations. It may be that the high percentage of recovery in predislocations is not due to early treatment, but to the fact that the patients have suffered the least degree of prenatal damage.

The evidence, therefore, seems to the author to show that the chief and essential factors which determine the end result in dysplasia of the hip are the nature and degree of the primary alterations of normal morphogenesis, and the ability or inability of the growth processes to overcome, under favorable conditions, the primary damage. The time factor is of importance in that, by early adequate treatment, a normal mechanical stimulation is

FIG. 7-A

FIG. 7-B

R. T., a girl. May 14, 1932. Marked congenital deformities were present at birth: bilateral dislocation of hips, defect of right femur, and deformities of hands and feet.

provided for growth; but it is of no avail in the production of a "perfect" hip unless the primary factors are favorable to this end.

PRIMARY FACTORS THAT DETERMINE THE END RESULTS OF TREATMENT IN CONGENITAL DYSPLASIA OF THE HIP JOINT

Perfect and excellent end results can be obtained only in the predislocations and in those dislocations which can be reduced bloodlessly, because within these groups are those hips which have suffered the least primary damage and have the greatest residual power of growth. This statement does not mean that all predislocations and all dislocations amenable to bloodless reduction become perfect. It does mean, however, that, if open reduction must be done, the structural changes in the hip are of such a nature that a perfect hip cannot develop.

This broad assertion is based on the author's observations in the thirty-three cases (13.75 per cent.) in which the hips were operated upon before four years of age because they were irreducible by manipulation. No record of a "perfect" end result appears among them, although stability was obtained by operation in most of them and a useful amount of motion was achieved in many. These thirty-three operations, and the fifty-two which were performed because of failure of bloodless reduction, in the selected group of cases discussed in this paper and the many others tabulated, revealed the defects which make the development of a perfect hip impossible. Excluded from discussion are the 6 per cent. born with irremediable dislocations (see General Statistics) and the many old irreducible dislocations with marked secondary pathological deformities, in which the primary pathological condition could not be determined.

In a general way, the hips that *require* open reduction present the more serious defects. The thirty hips that were operated upon within three years after bloodless reduction had less marked defects, although some of them were of the same nature as those in the first group. The twenty-two cases in which operations had been performed from four to twenty years after reduction, which had been classed as satisfactory during these years, presented, for the most part, only the least serious defect,—namely, persistent aplasia of the acetabular roof, accompanied in a few cases by aplasia of the femoral head.

Let it be understood that the author does not deny, but, on the contrary, strongly affirms that satisfactory and even perfect *functional* results may be obtained by operative procedures for the correction of these various deformities of the hip[2–5]. The degree of improvement varies inversely with the degree of deformity, and even those with perfect function show some degree of anatomical imperfection (Figs. 12-A to 15-B, inclusive[4]).

Dysplasia, or probably better, *aplasia of the acetabular roof* is common to all predislocations and dislocations. If it is not associated with other structural defects of the hip joint, it offers the least obstacle to the production of a perfect hip. It appears to constitute the least departure from the normal morphogenesis of the hip. Under favorable mechanical conditions, Nature is able to develop a normal acetabulum quickly in most cases of predislocation, and more slowly in that smaller percentage of the cases of dislocation that achieve perfection. In addition, this defect of the hip, if it persists, is more easily and satisfactorily remedied by operative procedure than is any other defect. (See illustrations of shelf or buttress operation in Type I dislocations[2–5].)

Aplasia of the femoral head is manifested by delayed, irregular, or incomplete calcification, as seen in the roentgenograms. This condition was formerly, but erroneously, called Legg-Perthes disease, even by the author in some of his earlier papers. It can be observed in practically all cases of predislocation and dislocation. (See illustrations[5] and Figs. 4-A to 5-E, inclusive.) Nature may correct this condition early or late during the growth of the hip, as the acetabulum becomes perfect. The cotyloid and the epiphyseal growth appear to proceed *pari passu*. An unusual condition is illustrated in Figures 9-A, 9-B, and 9-C[4]. The bilateral dislocations were reduced bloodlessly when the child was seventeen months of age. The acetabula thereafter showed evidence of rapid growth that promised normal development, but the femoral heads showed no growth. At the end of five years the neck and head of each femur consisted of a round knoblike mass of bone, which lay beneath a fairly well-developed acetabular roof. This case indicates that dysplasia of the head may occur independently and prevent the formation of a perfect hip. Possibly in this case dysplasia of the head and of the femoral neck are bound together inseparably.

If the final result is a deformed socket, the head, if it remains within it, is similarly deformed. It has been noted by the author and by many other observers that the ligamentum teres, which carries a blood supply to the growing head, is frequently absent. Possibly its absence can account for the more marked cases of epiphyseal dysplasia, but it cannot explain the fact that *all* dislocations present the same dysplasia and that the dislocation becomes corrected as the acetabular dysplasia is corrected.

The opinion has been prevalent, and it still persists, that this aplasia of the head is due to excessive violence in manipulation during reduction. I do not deny that a soft head may be injured by such violence, and I even go as far as to prevent weight-bearing in cases of prolonged dysplasia (as in the treatment of true Legg-Perthes disease); but I cannot consider that this condition, which is a defect common to all dislocations both before and after reduction, is an evidence of excessive violence.

The *more severe deformities* of the structures of the hip joint, which prevent complete bloodless reduction and which, in the author's opinion, render the development of a perfect hip impossible, have often been enumerated. They consist chiefly of inequality in the size of the acetabulum and the head, deformities of the head, capsular constrictions, shortness of the neck, and, of great importance, high insertion of the capsule on the femur.

These pathological conditions and the surgical procedures adapted to their improvement have been described[2,3]. During the thirteen years subsequent to the last of these publications, the author has been impressed with the relatively high frequency of Type V (short neck and high attachment of the capsule) in children under four years of age who were operated upon because bloodless reduction was found to be impossible (Figs. 6-A and 6-B). While the operations described for these different conditions are very efficacious

in giving stability to the hip and in improving its function, yet not a single record shows the production of a "perfect" hip when any of the severe deformities were present.

Anteversion of the neck and *superior dislocation* (erroneously called "anterior dislocation") merit special discussion because of a difference of opinion as regards their nature and importance.

Many, if not all, dislocations present some degree of *anteversion*, although it is not always easy to prove this in the early roentgenograms. It has been the author's experience, as previously stated, that, if the dislocation can be reduced and the reduction maintained (fixation of the extremity in the position of internal rotation may be necessary in the more marked cases of anteversion), the normal growth processes in the reduced hip gradually bring about a correction of anteversion (Figs. 18-A to 18-E[5] and Fig. 2). More marked degrees of this condition may be found to accompany the serious deformities which make bloodless reduction impossible. This is particularly true in Type V (shortening of the femoral neck) (Figs. 6-A and 6-B). The shortening and the version are probably both due to the same pathological process. A rotation osteotomy will not serve to cure a dislocation, if other conditions are present to prevent it. Several cases have been seen in which one and even two osteotomies had been performed, with a final result of incurable dislocation. If primarily complete reduction was obtained in these hips, and if a rotation osteotomy of the shaft of the femur produces a complete and permanent compensatory correction of the anteversion of the neck, then some other condition must have caused the redislocation. Possibly the redislocation occurred because of a persistent aplasia of the acetabulum, the defect which can most easily and satisfactorily be corrected if taken in time; possibly it was due to one or more of the more serious deformities enumerated in a preceding paragraph. It is the author's opinion that the surgeon should not place his sole reliance on a compensatory rotation osteotomy of the femur, if defects other than anteversion are present in the hip; and, also, that other serious defects usually, if not always, accompany marked anteversion. A number of other orthopaedic surgeons do not agree with this opinion, and only continued observation by all will reveal the truth.

"Anterior" Congenital Dislocation of the Hip

It is accepted in surgical literature that, in an anterior dislocation of the hip, the head of the femur rests upon the anterior plane of the innominate bone, and in a posterior dislocation it rests upon the posterior plane. Nélaton's line marks the ridge or apex between these two planes[1]. In the congenital dislocations in question, the head of the femur lies below the anterior superior spine of the ilium, on the ridge between the two planes. It cannot slip forward upon the anterior plane and become a pubic dislocation, because of the firm attachment of the tensor fasciae femoris to the margin of the ilium, in the notch between the superior and inferior spines; and it never lies medial to the fascial plane between the tensor and the sartorius muscles. This type should be called a "superior" dislocation, because the head of the femur is directly above the center of the acetabulum in the weight-bearing position and it lies fully on neither plane of the pelvis. This condition is frequently accompanied by marked anteversion of the neck, which causes the head to become more prominent on the anterior aspect of the pelvis. Internal rotation of the femur may make the prominence of the head less apparent. I do not know why the head of the femur occupies this position. I am inclined to believe that morphologically this is a true posterior dislocation; that the head has emerged from the acetabulum in the weak spot of the cotyloid rim between the pubes and the ilium (in many roentgenograms one can observe a groove in this position); that the upward migration of the head is deflected by the straight head of the rectus femoris and by the main limb of the strong iliofemoral ligament, attached to the anterior inferior spine of the ilium; and that it thence pursues its upward course on the ilium in a position immediately posterior to its anterior margin, and comes to rest eventually beneath the anterior superior spine or slightly posterior to it.

This "superior" dislocation of the hip presents well-recognized difficulties in reduction and maintenance of reduction, owing chiefly to the marked aplasia of the cotyloid rim and the marked deformity of the neck. In my experience, open reduction, with the construction of an efficient acetabular roof by a properly performed shelf or buttress operation, is the only effective means of treatment. These hips can never become "perfect".

Finally, approximately 6 per cent. of all dislocations present such severe deformities that reduction by manipulation or open operation is impossible (Figs. 7-A and 7-B). Only some method of palliative operation may be available to reduce the amount of disability at a later time.

CONCLUSIONS

1. Approximately 25 per cent. of dislocated hips may be expected to become perfect or excellent after bloodless reduction. This percentage is increased to 35 in hips in which the dislocation is reduced during the first three years of life.

2. Another 15 per cent. of hips may be expected to become functionally satisfactory for a varying number of years, with the understanding that eventually symptoms of fatigue, pain, and limp may arise. This percentage is increased to 20 when the dislocation has been reduced before the end of the third year.

3. Failure (subluxation or recurrence of complete dislocation) may be expected in 60 per cent. of all primarily reducible dislocations, and in 45 per cent. of those reduced in the first three years.

4. The form and the degree of the dysplasia of the various structures of the hip joint which is present at birth, and the ability or inability of resumption and continuation of normal growth after reduction, are the essential factors that determine the end result.

5. The time factor (age of the child at time of reduction) is of secondary influence, inasmuch as the end results are better in hips in which the reduction was carried out during the first three years of life than in those reduced after this age. It is not this factor, however, which determines the result in the large group of hips in which reduction was achieved early. The high percentage of cures resulting from the treatment of predislocation seems to prove the great importance of the time factor; but this is open to question, because many cases of predislocation are cured spontaneously or by minimal treatment.

6. The "perfect" end results are to be found only among those cases that are amenable to bloodless reduction. If open operation is necessary for reduction, one can always observe the presence of one or more of those structural deformities that make the development of a perfect hip impossible. Of marked importance and frequency among these are the deformities of the neck of the femur and a high capsular attachment.

7. Various operative procedures are of great value to restore stability of the hip and to improve its function. Complete restoration of normal function and a close approach to normal anatomy may be obtained by a timely, wisely selected, and properly executed operation in cases of prolonged acetabular aplasia, unaccompanied by other, more serious deformities.

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THE RESULTS OF TREATMENT OF CONGENITAL DISLOCATION OF THE HIP IN INFANCY*

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The normal development of the hip is dependent upon an intimate relation between the acetabulum and the head of the femur. In congenital dislocation of the hip, this relation is disturbed until the dislocation has been reduced. Long ago, Putti emphasized the importance of the early diagnosis and immediate reduction of the dislocated hip. Clinical experience, however, offers no definite assurance that early reduction will invariably bring about normal hip function. This review was undertaken for the purpose of exposing the reasons for the imperfect results among patients who had received treatment in early life for congenital dislocation of the hip.

The following analysis of the results of treatment of congenital dysplasia and of congenital dislocation of the hip is based upon a study of 112 such disorders, which occurred in eighty-six patients, upon whom treatment was commenced within the first three years of life. This analysis cannot be termed a study of the end results of treatment; rather it is a report of the early results, covering a period of from one to thirteen years after the commencement of treatment. The patients reviewed were unselected, and constitute all of those known to have been treated in two institutions and a private practice during a period of twenty-three years and one of fifteen years, respectively.

The accuracy of a report concerning the results of treatment is enhanced by the number of years during which the patient has been observed. A few of the infants reported have been observed for only one or two years; but, in the age group covered by this report, even this short period was considered sufficient to indicate the trend of development of the hip joints. However, the majority of the patients have been observed for from four to thirteen years following the treatment.

Throughout this report, the simple terminology for hip disorders suggested by Hart has been used. The types of disorders have, therefore, been designated either as dysplasia or as dislocation of the hip. The first term applies to those hips which lack normal development of the roof of the acetabulum, and the second designates those hips in which dysplasia is found in conjunction with some outward or upward displacement of the head of the femur. Such a simple classification seems entirely adequate to express the various degrees of displacement about the hip joint. No case of arthrogryposis has been included.

A review of the results obtained by treatment would be incomplete without some mention of the type of treatment employed. The patients included in this analysis were treated by a number of surgeons, and, therefore, the type of treatment has varied considerably. In general, however, the treatment of the past consisted of closed reduction by the method of Denucé. When the closed reduction or reductions failed, an open reduction, with or without reconstruction of the shelf of the acetabulum, was employed. In recent years, the original manipulation has been preceded by traction upon the extremity until the femoral head approached the level of the hip joint. The traction and abduction method of Putti, as modified by Coonse (Fig. 1-A), has usually been employed for

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FIG. 1-A

FIG. 1-B

Fig. 1-A: Patient on a Coonse modification of a Putti frame.

Fig. 1-B: Same child on a Ponseti bar.

this purpose. Following traction, the head of the femur was simply rotated into the position in which it was most stable; although, in some instances, a more formal manipulation was also employed. An osteotomy to rotate the femur was used fifteen times upon the patients in this age group.

When plaster casts were used for fixation, the average period of such treatment was nine months. In the past two and one-half years the abduction bar described by Ponseti (Fig. 1-B) has been substituted for the plaster cast, approximately five months after reduction of the dislocated hip, for all patients observed within the first year of life and for many of those observed within the second year of life. Where some formal method of reduction was used, the treatment required a period of hospitalization. Treatment with the Ponseti bar, however, has been carried out by the parents at home. Some patients from the ages of one and one-half to three years have been treated for a short period in the hospital by traction on the Coonse frame, until reduction of the displacement had been effected. Immediately thereafter the Ponseti bar was substituted, so that a long period in the hospital was not necessary.

The authors' experiences do not permit definite conclusions concerning the age limits within which the Ponseti bar is effective; but when it has been employed in patients under the age of one and one-half years, no failures in effecting satisfactory reduction of the dislocation of the hip have resulted.

The abduction bar offers many advantages, in addition to elimination of the hospital stay. Among these is the complete mobility of the hip, permitted by the bar. Furthermore, the children have been taken out of the bar for one hour daily for the purpose of bathing and for unfettered exercise. While wearing the bar, the patients may crawl, climb, and stand. One disadvantage of the abduction bar is the forced position of genu valgum which follows wide abduction of the legs, but this has proved transient, as evidenced by the absence of permanent deformity of the knees after final removal of the bar.

METHOD OF ANALYSIS

A review of the literature indicates a lack of uniformity in the methods used to record the results of treatment for congenital dislocation of the hip. It is, therefore, difficult to make comparisons of the results reported in the medical literature. In 1941, Severin reported an end-result study in which he used a clear and concise method of expressing both the anatomical and the functional results which occurred after the treatment of congenital dislocation of the hip. In the opinion of the authors, when the effects of treat-

ment are to be reported, the classification of Severin, as modified by Ponseti, is worthy of general adoption.

These classifications of the anatomical and the functional results, which have been adopted for the present report, are as follows:

Anatomical Results (Severin)

Group I Normal hips;
Group II Moderate deformity of the femoral head or neck or acetabulum, but otherwise normal conditions in the joint;
Group III Dysplastic hips without subluxation;
Group IV Subluxation;
Group V The head articulating with a secondary acetabulum in the upper part of the original acetabulum;
Group VI Redislocation.

Functional Results (Ponseti)

Group I No symptoms;
Group II Slight pain in the hip on excessive walking;
Group III Limp, free motion, and no pain;
Group IV Limp and limitation of motion, but no pain;
Group V Limp and pain;
Group VI Limp, limitation of motion, and pain.

The term "subluxation," used by Severin to designate Group IV, is not particularly objectionable since, by its placement in the classification, it is obviously used to describe moderate degrees of outward, or outward and upward, dislocation of the head of the femur. The authors of the present report have ventured to add a Group I-A to Ponseti's classification of the functional results, in order to include a previously unseparated number of patients who show slight restriction of motion, even though they have no symptoms to suggest that the hip joint is imperfect.

Roentgenography is the sole means by which the anatomical condition of the hip may be judged. The interpretation of the roentgenograms should include specific in-

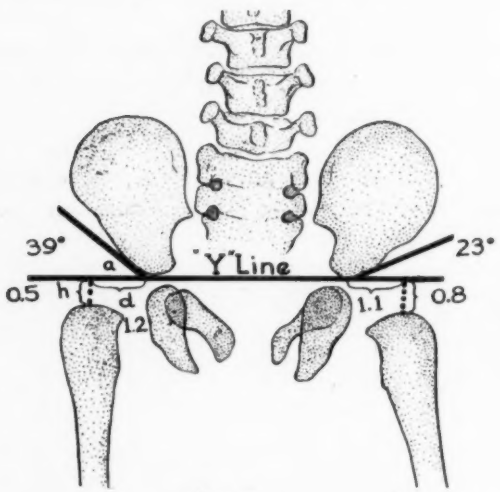

FIG. 2

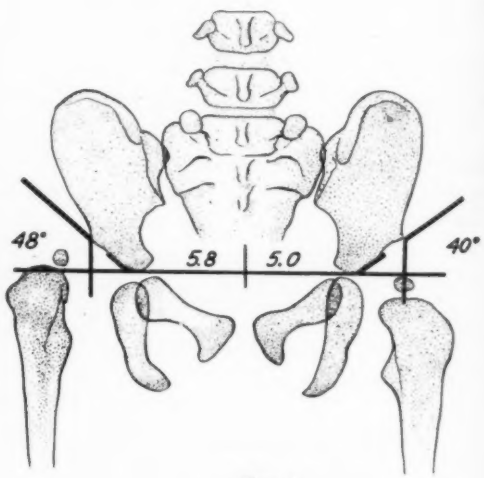

FIG. 3

Fig. 2: Hilgenreiner's measurement. *a*, The acetabular index; *h*, the position of the diaphysis, measured from its most proximal shadow to the Y line; *d*, the distance from the most proximal shadow of the diaphysis to the acetabular floor.

Fig. 3: Unilateral dislocation at age of one year. Shows the acetabular index, Perkins perpendicular line from the upper and outer border of the acetabulum, and the Y coordinate.

TABLE I

CONGENITAL HIP DISORDERS OBSERVED IN EIGHTY-SIX PATIENTS

Age at Reduction	Dysplasia		Dislocation		Total Cases
	Unilateral	Bilateral	Unilateral	Bilateral	
First year	4	0	9	4	17
Second year	7	0	39	12	58
Third year	1	0	22	14	37
Totals	12	0	70	30	112

formation concerning both the acetabulum and the head and neck of the femur, as well as their relation to one another. The measurements of Hilgenreiner, as reported by Severin, satisfy these requirements, and they have been used in the interpretation of the roentgenograms which were surveyed in this study. In this measurement (Fig. 2) the transverse or Y line extends between the tips of the ilia at the region of the triradiate cartilage. The slope of the acetabulum is measured from the tip of the ilium to the upper and outer portion of the acetabulum. The angle between the line marking the roof of the acetabulum and the Y line has been aptly designated by Kleinberg and Lieberman as the "acetabular index" (Fig. 2). A third line, drawn perpendicularly from the Y line to the highest point of the upper femoral diaphysis, permits the measurement of the distance of the femoral diaphysis either downward or upward from the Y line, and also its distance outward from the tip of the ilium at the base of the acetabulum. The measurement of Perkins (Fig. 3), which is a perpendicular line from the upper and outer border of the acetabulum to the Y line, is also helpful in indicating the position of the head of the femur.

The Y coordinate for the hip joint has also been recorded upon the roentgenograms reviewed in this study. This is the measurement from the line of gravity of the body, as represented by a longitudinal line through the mid-sacrum, to the center of the head of the femur. Attention has been directed to the importance of this measurement by Ponseti, in his analysis of the results after the shelf operation for congenital dislocation of the hip. He observed a direct relation between an abnormal separation of the center of motion of the hip joint from the line of gravity and a poor functional result.

The authors have made numerous unsuccessful attempts to find an accurate method for recording the anteversion of the neck of the femur, and have also recorded various other measurements which have not proved helpful in this analysis.

The interpretation of measurements made upon the roentgenograms may be both difficult and misleading. If comparisons are to be made, a standard technique must be employed and the roentgen tube must be well centered over the pelvis, which has been

TABLE II

POSITION OF HEAD OF FEMUR IN REFERENCE TO Y LINE

	First Year (*Centimeters*)	Second Year (*Centimeters*)	Third Year (*Centimeters*)
Unilateral dislocation (Average level)			
Normal hip	−0.6	−0.52	−0.45
Dislocated hip	−0.23	+0.55	+1.0
Average displacement	0.37	1.07	1.45
Bilateral dislocation	+0.55	+0.93	+1.1

TABLE III

MEASUREMENTS OF "NORMAL" ACETABULA IN PATIENTS WITH UNILATERAL DISLOCATION

	High (*Degrees*)	Low (*Degrees*)	Average (*Degrees*)
First year (10 hips)	27.5	15	23.6
Second year (40 hips)	26	9	20
Third year (10 hips)	24	9	18.5

placed in a symmetrical position with the knees together and the patellae uppermost. When any doubt exists concerning the hip joint, the roentgenograms should be repeated at intervals. While the mathematical accuracy of the interpretation of the roentgenograms may be open to question, nevertheless the comparison of the two hips and of roentgenograms taken in series provides relative accuracy upon which a judgment may be based.

The evaluation of the functional results has either been based upon a personal examination by one of the authors, or has been taken from the records of the other orthopaedic surgeons who examined the patient.

ANALYSIS

Age of Patients at Time of Treatment

Of the 112 disorders of the hip which were reviewed in this analysis, seventeen or 15 per cent. were in patients treated under the age of one year; fifty-eight or 52 per cent. in the second year of life; and thirty-seven or 33 per cent. in the third year of life (Table I). The ages at which the diagnosis of dysplasia or dislocation of the hip was established range from eight days to thirty months. The records indicate that treatment of the dislocation was often not considered of an urgent nature, as evidenced by its postponement for a number of months after diagnosis. An indication of the increased awareness of dislocation of the hip is the fact that, in recent years, a greater number of infants have been referred for treatment. In this group of patients the urgency of the treatment has been thoroughly recognized.

TABLE IV

ACETABULAR INDEX IN 112 HIPS *

Age Group in which Treatment Was Started	No. of Months Required for Acetabular Index to Reach 27.5 Degrees or Less									Cases in which Acetabular Index Did not Reach 27.5 Degrees at Last Examination	
	6	9	12	15	18	24	30	36	More than 36	Observed Less than 36 months	Observed More than 36 months
First year	4	2	5	1	2					2	0
Second year		3	10 **	2	2	5	3	2	3 †	14	12
Third year			3	2			3	2	6	4	17

* In three hips the acetabular index was less than 27.5 degrees at start.

** One followed operation. † Two followed operation.

TABLE V

DEVELOPMENT OF ACETABULUM AND FEMORAL HEAD FOLLOWING THE TREATMENT OF CONGENITAL HIP DISORDERS

Type of Treatment	No. of Cases	Acetabular Index Remaining above 27.5 Degrees	Aseptic Necrosis
Abduction frame	32	6	4
Traction and manipulation	13	9	7
Manipulation without traction	31	7	23
Remanipulation	8	7	6
Multiple manipulations (three or more)	3	2	2
Open reductions with or without shelf operation	21	16	16
Shelf operation only	2	2	1
No treatment	2	0	0

Types of Displacement

Dislocation occurred in 100 instances; in fifteen patients it was bilateral (thirty hips). There was a definite relation between the degree of displacement of the hip and the age of the patient, as shown in Table II.

Dysplasia without dislocation of the head of the femur was present in twelve hips; in eleven of these, it was accompanied by dislocation of the opposite hip. In this series, the absence of other instances of dysplasia, either unilateral or bilateral, is difficult to explain, particularly since a careful search of the records has been made. The apparent discrepancy between this study and other reports may lie in the fact that the authors have considered even a moderate degree of displacement of the head of the femur as constituting a dislocation of the hip, rather than a dysplasia with subluxation. Nevertheless, the authors feel that adequate justification for using the simple classification of Hart lies in the fact that there was rarely agreement between them or among several roentgenologists as to whether a particular roentgenogram showed dysplasia with subluxation or dislocation of the hip.

Development of the Hip Joint as Revealed by Roentgenograms

The interpretation of the roentgenograms may furnish only relative, and not absolute, information concerning the hip joint. Roentgenograms taken with the lower extremities externally rotated and abducted and with the pelvis rotated backward present an entirely different acetabular index than those taken with the extremities together and the patellae uppermost. In roentgenography, therefore, a uniform method must be adopted, if comparison is to be made of the measurements of the anatomical relations of the hip joint.

a. The Acetabular Index

It is difficult to make any definite statement concerning the normal measurements of the acetabular index at various ages. Kleinberg and Lieberman reported that an acetabular angle of 27.5 degrees was normal for newborn infants. They also found an average angle of 20 degrees in their study of the roentgenograms of infants between one and two years of age. Measurements of a small number of normal hips, made by the authors, show a great variation of the acetabular index for infants in the first three years. These measurements ranged from a low of 12 degrees in a baby of four months to a high of 28 degrees in a child of one year. Further, in a review of the literature, no information

FIG. 4-A

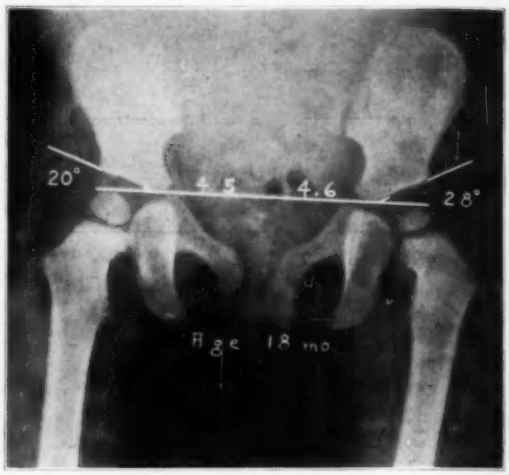

FIG. 4-B

Fig. 4-A: J. A. Unilateral dislocation in infant, aged six months.
Fig. 4-B: At age of eighteen months, after twelve months on Ponseti bar, differences between the acetabular index and the Y coordinate are much less.

FIG. 4-C

At age of thirty months, after twenty-three months on a Ponseti bar. The Y coordinates are now equal and the left acetabular index is within normal limits.

could be found pertaining either to the rate or to the degree of descent of the acetabular index for each year of life.

In the dysplasias and dislocations reviewed in this report, the acetabular index of the abnormal hip varied from 27.5 to 55 degrees. Most of the hip joints, however, showed an acetabular index measuring from 30 to 40 degrees at the time of the first examination. For the patients who had unilateral dislocation, without dysplasia of the opposite hip, the measurements of the so-called "normal" acetabulum are shown in Table III.

In the present analysis, 27.5 degrees was selected arbitrarily as a fair estimate of the upper limit of the normal acetabular index in infancy. The time required for the acetabular index to reach 27.5 degrees or less was recorded for each of the hips in this series. As indicated in Table IV, in fifty-one hips (45.5 per cent.) the acetabular index dropped to 27.5 degrees within a period of three years, while nine hips (8 per cent.) required more than three years to reach that limit. In twenty-nine hips (25.9 per cent.) which were observed for a period of from three to thirteen years, the acetabular index failed to drop to the angle of 27.5 degrees. In twenty hips (17.9 per cent.) the index had not dropped to 27.5 degrees at the time of the last examination. These patients were observed for a period of from one to just under three years. In three hips (2.7 per cent.) a dislocation occurred, even though the acetabular index was at all times less than 27.5 degrees.

The time required for the descent of the acetabular roof (Figs. 4-A, 4-B, and 4-C) is of interest when viewed in relation to the age at which treatment of the dislocation was begun. Of the patients treated within the first year of life, all but two showed descent of the

TABLE VI

DIFFERENCE BETWEEN Y COORDINATE OF DISLOCATED AND NORMAL HIP

Treatment Started	No Difference	Less than 0.5 Centimeter	0.5 to 1.0 Centimeter	Over 1.0 Centimeter	Total Cases
First year	4	6		1 *	11
Second year	7	12	15	4	38
Third year	3	5	3	11	22
Totals	14	23	18	16	71

* After operation.

acetabular index within a period of eighteen months. These two patients had been observed for only one year, at the end of which the acetabular index had not yet reached 27.5 degrees. In those patients treated during the second and the third years, the descent of the acetabular index appeared more gradual than during the first year, and, in nearly one-half of the patients, never dropped as low as 27.5 degrees. A survey of the fifty-one hips showing a drop to 27.5 degrees or less within three years revealed that many approached the acetabular index of the normal, undislocated hip, but that only six actually reached that acetabular index.

In an attempt to determine the response of the acetabulum to the various types of treatment, the hips under review were segregated, according to the method of reduction which had been employed (Table V). The roof of the acetabulum failed to drop to 27.5 degrees in thirteen (20 per cent.) of the sixty-three hips which were treated either by abduction or by a single manipulation. The same failure was noted in nine (70 per cent.) of thirteen hips which were subjected to traction and manipulation, and in twenty-seven (80 per cent.) of thirty-four hips in which operation or repeated manipulations were required to bring about a reduction. These data might easily be misinterpreted, since the traction, the remanipulations, and the operations were usually employed in the older patients, or in those upon whom the simple methods had failed. Moreover, the simple

TABLE VII

Y COORDINATE OF FINAL ROENTGENOGRAM IN CASES OF BILATERAL DISLOCATION

Age at Beginning of Treatment (*Months*)	Right Hip		Left Hip		Difference (*Centimeters*)
	Y Coordinate (*Centimeters*)	Group	Y Coordinate (*Centimeters*)	Group	
29	8.3	V	7.8	V	0.5
33	9.3	II	9.9	II	0.6
24	9.0	IV	7.1	IV	1.9
32	6.7	I-A	6.4	I-A	0.3
15	7.9	I-A	9.3	I-A	1.4
19	5.9	I	6.5	I-A	0.6
3	5.0	I	5.0	I	0
34	7.5	IV	8.5	IV	1.0
29	8.4	IV	5.9	IV	2.5
24	8.4	I-A	7.8	I-A	0.6
6	5.7	I	5.7	I	0
24	10.5	VI	9.5	VI	1.0
30	9.0	IV	7.5	IV	1.5
24	5.6	I	5.6	I	0
30	6.0	I	6.0	I	0

TABLE VIII

DIFFERENCE BETWEEN Y COORDINATE OF DISLOCATED AND NORMAL HIP

Functional Results	No Difference	Less than 0.5 Centimeter	0.5 to 1.0 Centimeter	Over 1.0 Centimeter	Total Cases
Group I					
No symptoms	12	21	15	0	48
Group I-A					
Slight limitation of motion; no symptoms	1	0	1	4	6
Group II					
Slight pain	0	0	0	0	0
Group III					
Limp, free motion, and no pain	0	2	2	3	7
Group IV					
Limp, limitation of motion, but no pain	1	0	0	8	9
Group V					
Limp and pain	0	0	0	0	0
Group VI					
Limp, limitation of motion, and pain	0	0	0	1	1
Totals	14	23	18	16	71

methods were more commonly applied to the younger patients with the least deformity, and, therefore, those in whom the acetabulum was in a more plastic state. Nevertheless, it may be concluded that the development of the acetabulum was the greatest in those patients upon whom the least traumatic methods were employed.

b. The Y Coordinate

The Y coordinate was measured on all of the earliest and on all of the latest roentgenograms of the hips included in the study. In the earliest films, this measurement was helpful in determining the amount of displacement of the head of the femur. When the head of the femur had not yet ossified, the distance was measured from the mid-line to

FIG. 5-A

FIG. 5-B

Fig. 5-A: Child aged three years; one year after operation. The left femoral head is not well seated in the acetabulum.

Fig. 5-B: At age of nine and one-half years; a rotation osteotomy has been done. The left femoral head is still not well seated.

TABLE IX

ANATOMICAL RESULTS IN RELATION TO AGE AT WHICH TREATMENT WAS STARTED

Anatomical Results (Severin's Classification)	First Year		Second Year		Third Year		Total	Per cent.
	Dysplasia	Dislocation	Dysplasia	Dislocation	Dysplasia	Dislocation		
Group I Normal hips	2*	8	3	7			20	17.9
Group II Moderate deformity of head, neck, or acetabulum, but otherwise normal	2	4	4	20		12	42	37.5
Group III Dysplastic hips without subluxation				18	1**	10	29	25.9
Group IV Subluxation				2		1	3	2.6
Group V Head articulating with secondary acetabulum in upper part of original acetabulum				3		11	14	12.5
Group VI Redislocation		1		1		2	4	3.6
Totals	4	13	7	51	1	36	112	100.0

*One case was untreated.
**This case was untreated.

the highest point on the diaphysis of each femur. Whenever ossification of the head of the femur was apparent, the measurement was made in the usual manner. Outward displacement of the head of the femur, which increases the Y coordinate, may be caused by a thickening of the bony floor of the acetabulum, by soft tissues interposed between the acetabulum and the head of the femur, by a maladaptation between the size of the head of the femur and of the acetabulum, or by an enlargement of the head of the femur (Figs. 5-A and 5-B).

From the final films of the seventy-one unilateral dislocations, in which the opposite hip was normal, measurements of the Y coordinate were made for the three age groups (Table VI). The measurements indicate that the institution of treatment in early life has an important effect upon the adaptation of the femur to the acetabulum.

Of the fifteen patients who had bilateral dislocation of the hip, the Y coordinate was rarely the same for each hip (Table VII). In the eleven dysplastic hips the Y coordinate was, of course, always less than that of the dislocated hip on the opposite side. In the seventy-one cases of unilateral dislocation, the Y coordinate was also compared with the functional result (Table VIII).

With one exception, all of the patients with an increase in the Y coordinate of less than one centimeter had good functional results. The exception was a boy whose hip had been treated unsuccessfully by an open reduction before he was twelve months old. Reduction was achieved by a closed manipulation, but thereafter the hip remained quite stiff. In four patients of Group III, the Y coordinate showed an increase of less than one centimeter as compared with the normal side. Re-examination of these patients showed that they had good functional results, in spite of the elongation of the Y coordi-

TABLE X

ANATOMICAL RESULTS IN RELATION TO METHOD OF TREATMENT

Anatomical Results (Severin's Classification)	Abduction Frame	Traction and Manipulation	Manipulation	Remanipulation	Multiple Manipulations *	Open Reduction with or without Shelf Operation	Shelf Operation Only	No Treatment	Total
Group I	12	1	6					1	20
Group II	18	6	12	3	1	2			42
Group III	2	4	9	3	1	8	1	1	29
Group IV		1	1			1			3
Group V		1	3	1	1	7	1		14
Group VI				1		3			4
Totals	32	13	31	8	3	21	2	2	112

* Three or more manipulations.

nate. Among the hips with an increase in the Y coordinate of over one centimeter are four which can be classified in Group I-A; the others are in the groupings which designate imperfect function of the hip. In the bilateral dislocations (Table VII), the Y coordinate was determined for each hip. With one exception, where the Y coordinate was less than seven centimeters, all of the hips which were measured were placed in functional Groups I, II, or III. The one exception was the unstable hip in which the Y coordinate measured

TABLE XI

THE FUNCTIONAL RESULTS IN RELATION TO AGE AT WHICH TREATMENT WAS STARTED

Functional Results (Ponseti's Classification, Modified)	First Year		Second Year		Third Year		Total	Per cent.
	Dysplasia	Dislocation	Dysplasia	Dislocation	Dysplasia	Dislocation		
Group I No symptoms	4*	12	7	34	1*	10	68	60.7
Group I-A No symptoms; slight limitation of motion				9		4	13	11.6
Group II Slight pain in the hip on excessive walking						2	2	1.8
Group III Limp, free motion, and no pain				2		5	7	6.3
Group IV Limp and limitation of motion, but no pain		1**		4		12	17	15.2
Group V Limp and pain						2	2	1.8
Group VI Limp, limitation of motion, and pain				2		1	3	2.6
Totals	4	13	7	51	1	36	112	100.0

*One case was untreated.

**Operated upon elsewhere at 8 months of age.

TABLE XII

FUNCTIONAL RESULTS IN RELATION TO METHOD OF TREATMENT

Functional Results (Ponseti's Classification, Modified)	Abduction Frame	Traction and Manipulation	Manipulation	Remanipulation	Multiple Manipulations*	Open Reduction with or without Shelf Operation	Shelf Operation Only	No Treatment	Total
Group I	32	9	18	2	1	4		2	68
Group I-A		3	5	2	1	1	1		13
Group II			2						2
Group III			1	2		4			7
Group IV		1	5	1	1	8	1		17
Group V						2			2
Group VI				1		2			3
Totals	32	13	31	8	3	21	2	2	112

*Three or more manipulations.

5.9 centimeters. On the other hand, where the Y coordinate was over seven centimeters, most of the hips were placed in functional Groups IV, V, or VI. Two patients were placed in Group I-A in spite of Y coordinates of over seven centimeters. Both of these patients had moderate stiffness, which may explain the stability of the hips in question. One of the patients, with a Y coordinate of 9.3 centimeters on one side and 9.9 centimeters on the other side, was placed in Group II; and perhaps this rating is open to some question. In some of the patients with bilateral dislocation of the hip, it was noted that, in spite of a considerable difference in the measurements of the two hips, the functional results were reported as similar. It was not possible to re-examine all of these patients.

c. The Head of the Femur

In the younger patients, a delay in the ossification of the head of the femur was invariably present. This delay in development continued over a period of two or three years. In most instances, irregularities in the ossification and in the shape of the head of the femur appeared throughout the period of observation. Some of these irregularities were apparently caused by pressure from the impingement of the head of the femur against the rim of the acetabulum.

The development of the size and shape of the head of the femur was followed with interest. In the roentgenograms of some of the hips, the head of the femur appeared too

TABLE XIII

ANATOMICAL RESULTS COMPARED WITH FUNCTIONAL RESULTS

Anatomical Results	Functional Results						
	Group I	Group I-A	Group II	Group III	Group IV	Group V	Group VI
Group I	19	1					
Group II	34	3	2	2	1		
Group III	15	8		2	3		1
Group IV		1		1	1		
Group V				1	10	2	1
Group VI				1	2		1

large for the acetabulum. A great number became somewhat oval in shape or flattened, rather than assuming the characteristic spherical contour of the head of the normal femur.

d. Aseptic Necrosis

Aseptic necrosis was observed during or after the course of treatment in fifty-nine hips, or 52 per cent. of the total series (Table V). Of this number, the distribution, according to the age at which treatment was started, was as follows:

Year	No. of Cases	Aseptic Necrosis (No.)	Aseptic Necrosis (Per Cent.)
First	17	2	12
Second	58	34	59
Third	37	23	62

The relation of the type of treatment to aseptic necrosis is noted in Table V. This indicates that aseptic necrosis developed in only 12 per cent. of the hips treated by abduction, whereas the incidence of aseptic necrosis was 54 per cent. and 74 per cent., respectively, in the hips that required reduction by traction and manipulation or by manipulation alone. Undoubtedly, the age of the patient at the time of treatment also had an important bearing upon the incidence of aseptic necrosis, since the least traumatic methods were used in the younger infants.

RESULTS

Anatomical Results

With the exception of the one hip in which a redislocation occurred, all of the hips in which treatment was started within the first year are placed in Groups I and II (Table IX). In the second year, approximately one-half of the hips are in these groups, while dysplasia of the acetabulum (Group III) occurs frequently. No hips in which treatment was delayed until the third year appear in Group I; only one-third of the hips appear in Group II, and the other two-thirds are distributed,—about half in Group III and the rest in those groups which designate a poor anatomical result.

It is well known that deterioration in the anatomical results may be expected with increasing age. This fact must be considered in the interpretation of the results noted in this report, since many of the patients have been observed for a short period only and few of them have reached the fourteenth year.

The anatomical results have also been tabulated with respect to the type of treatment employed (Table X); it may be seen that the majority of the hips treated by simple methods appear in Groups I, II, and III. The age of the patient, of course, has influenced the method used in effecting reduction of the hip.

Functional Results

Seventy-four per cent. of the 112 hips were placed in Groups I, II, and III, which represent hips showing excellent function. With the one exception noted previously, the hips of all patients in whom treatment was started in the first year appear in Group I (Table XI). Most of the hips treated in the second year responded favorably to treatment. Less than half of the patients treated in the third year are in the group of good results.

The functional results (Table XII) were also compared with the method of treatment which had been used. The greatest number of good functional results appeared among those who had received treatment of the least traumatic types. Practically all of the poor functional results occurred in those hips which had required either repeated manipulations or reduction by operation.

Comparison of Anatomical and Functional Results

Table XIII shows that all of the hips with normal anatomical ratings have excellent function, and that most of the hips with moderate anatomical deformity show excellent

functional results. It is also noteworthy that, among the dysplastic hips which were followed throughout the years of childhood, there was little or no disturbance of function. As might be expected, the poor functional results were in those hips which showed the greatest deviations from normal anatomical growth and development.

COMMENT

The authors do not wish to present any positive conclusions from the statistical analysis given here, but an attempt has been made to interpret the data included in this study. It is unfortunate that all of the patients could not have been examined by the authors, and that none could be followed into adult life. Nevertheless, it is to be hoped that some useful deductions may be drawn from this analysis.

The case histories indicate that both signs and symptoms of dysplasia and of dislocation of the hip were usually present, and were often recognized by the parents and the physician long before the diagnosis was established. These signs and symptoms were: the flexed and externally rotated hip, the increased thigh folds, the apparent shortening of the thigh, the "clicking" hip, the prominence of the trochanter and the head of the femur, the limitation of abduction, and the limp. The records also show that the importance of treating the dislocation or dysplasia is still not properly appreciated by members of the medical profession. In the present series, the absence of patients with simple dysplasia of the hip serves to emphasize the need for a more careful examination of the infant. Many such patients must have been overlooked and, while it is known that some dysplasias and dislocations undergo spontaneous recovery, it is certain that many such hips fail to develop normally.

The increased amount of displacement of the dislocated hip with each successive year of infancy lends support to the present theories concerning postnatal dislocation of the hip.

The difficulties attendant upon the interpretation of roentgenograms of the hip in the infant have been mentioned. These difficulties call for the adoption of standards for making the roentgen exposures, and for the collection of further information in reference to the growth and development of the infant hip joint.

In this study, the measurement of the roof appeared to be a reliable index of the growth of the acetabulum. After reduction of the dislocation, or in dysplasia, a wide abduction of the femur was followed by growth of the roof of the acetabulum. This is probably due to removal of the pressure of the femur from the rim of the acetabulum, as well as to the restoration of the normal pressure of the head of the femur in the hip joint. From a study of the hips in this series, there seems little doubt concerning the effect of reduction of the head of the femur in early infancy. Both the rate and the amount of growth of the acetabulum appear favored by a reduction performed in early life, before the occurrence of overgrowth and maldevelopment of the hip. With the advance of each year of infancy, the chance of securing a normal hip appears proportionately decreased.

Measurement of the Y coordinate gave definite information in relation to both the diagnosis and the effects of treatment of congenital dislocation of the hip. In the unilateral dislocations, an increased Y coordinate indicated that anatomical maldevelopment was present. In the measurements of the final roentgenograms, it was noticed that the Y coordinate approached the normal much more frequently in the hips having early treatment than in those in which the treatment had been delayed. As in Ponseti's study, a rather definite correlation was found between the Y coordinate for the hip and the function of the hip. In the unilateral dislocations, an increase of one centimeter over the normal gave rise to a disturbance of function. In the bilateral dislocations in this series, a Y coordinate greater than seven centimeters usually denoted a hip with poor function. The results of a maladaptation between the acetabulum and the head of the femur were evidenced by changes in the shape and size of the head of the femur. A number of the changes in the shape were the result of aseptic necrosis.

The present analysis indicates that both the postponement of treatment and the trauma at the time of reduction of the hip influence the incidence of aseptic necrosis of the head of the femur. The influence of the age of the patient upon the anatomical and functional results is seen throughout this analysis. The earliest treatment brought about the best growth and development of the hip and, therefore, was followed by the best functional results. Also, as mentioned previously, the simple, atraumatic methods may be employed with success in the treatment of young infants, thereby eliminating the complications which may follow the trauma of forced or repeated manipulations and the treatment by operation.

In the final analysis, it is apparent that age is the most important factor influencing the results of treatment of congenital dislocation of the hip.

SUMMARY

1. The standards of Severin and Ponseti have been used in an evaluation of the anatomical and functional results of treatment in 112 cases of dysplasia and dislocation of the hip.

2. Excellent or nearly excellent anatomical results were obtained in 55.4 per cent.; and 60.7 per cent. of the functional results were excellent. Deterioration with age would not be expected in this group. The best results were noted when the treatment used was the least traumatic.

3. Good anatomical results were produced by treatment in infancy in 81.3 per cent., and good functional results in 80.4 per cent., of the hips examined. The temporary nature of these results is not disputed, since all of the patients were less than fourteen years of age when the ratings were made.

4. The development of the acetabulum progressed slowly, indicating a probable need for longer periods of fixation after reduction of the hip. Delay in reduction of dislocations causes increasing maldevelopment of the hip, due in part to a thickening of the acetabular floor coincident with an increase in the Y coordinate. These factors are of importance in treatment and prognosis.

5. There is a direct relation between the early institution of treatment and the good results reported.

6. Even with an early diagnosis and an early application of treatment, the results of the treatment of congenital dislocation of the hip in infancy are far from perfect. Great effort must, therefore, be directed toward both earlier recognition of the dislocation and improvement of the present methods of treatment.

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BONE CHANGES IN THE CAT IN EXPERIMENTALLY PRODUCED INJURY TO THE PERIPHERAL NERVES *

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S. Weir Mitchell quoted the findings of Packard, in 1863, on arthropathies of the foot and knee, following compression of the sciatic nerve by a tumor. Since that time, a number of cases of neuropathies of the bones and joints have been reported, following peripheral-nerve injury and disease. Mitchell described a case in which extensive joint lesions developed after an injury to the brachial plexus, due to a dislocation of the shoulder.

The earlier reports dealt chiefly with simple atrophy of bone, which was attributed to disease and to changes in the joints. Among reports of atrophy of bone were the cases seen by Blum, Ogle, and Arnozan; these are mentioned by Bowlby, who, however, had not seen such cases himself and concluded that they were rare. Hirsch described a case of atrophy of the bone, resulting from injury to the median nerve. Goldscheider mentioned a case of atrophy of the bones of the hand, following disease of the ulnar nerve. A number of cases were described by Maliwa and by Lehmann.

Mitchell stated further that wounds or any lesions of nerves may produce inflammatory conditions in the joints, usually subacute, which so precisely resemble rheumatic arthritis in their symptoms and results that no clinical skill can discriminate between the two. Arthritic changes were referred to by McArdle, who described them as occurring when a nerve trunk was pierced, rubbed, or lacerated, but not when a peripheral nerve was severed, unless the nerve ends became bulbous or were caught in healing tissue. The opinion of that day was well expressed by Turney, who stated: "It is fairly certain that division of a nerve *per se* does not produce changes in the bone, except in so far as it causes paralysis. It is the partial division of nerves resulting in prolonged irritation that is the effective cause, and this, as we have seen, may be brought about by interference in any part of the reflex arc." With some intuition he said: "Had *x*-rays been available Weir Mitchell would undoubtedly have completed his account of 'glossy skin' by a description of the accompanying atrophy of bone".

Some years before, Sudeck had described an acute atrophy of bone, associated with inflammatory processes in the articulations, which he later called post-traumatic reflex atrophy of bone. About the same time, Kienböch added to the clinical findings and gave a description of the roentgenographic changes. This type of osteoporosis is most frequently found in the short bones of the hands and feet; next in order of frequency are the epiphyses of the metatarsals, metacarpals, and phalanges, and then the epiphyses of the long bones.

Although, because of concomitant injuries, such cases of osteoporosis have been considered as associated with peripheral-nerve injuries, they are not the consequence of injuries of large nerves or trunks. In the material of Herrmann, Reineke, and Caldwell, in which reports from a number of clinics are reviewed, it apparently was not found that peripheral-nerve injury, as apart from general, often minor, trauma, played a part.

In some cases, the disproportion between the severity of the pain complained of and the minor character of the trauma, or trauma at a distance, in addition to the changes in the mental attitude of the patient, led to a diagnosis of hysteria. Simons described cases in which, along with "psychogenic paralysis and contractures", similar osteoporosis was seen. In these cases the association of vasomotor, secretory, and other trophic changes in the skin and muscles indicated their identity with the cases of so-called physiopathic

* The work described in this paper was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Northwestern University.

reflex-nerve disturbances, reported by Babinski and Froment. Here there was a difference of opinion: Some, including Babinski and Froment, insisted upon an organic origin; others, as Roussy and Lhermitte, maintained that the basis was hysterical. In the author's experimental work, no such conditions have been encountered.

Numerous cases of bone and joint disturbances associated with lesions of the peripheral nerves were observed during World War I. In addition to types similar to those described by Sudeck and Kienböch, there were also reports of acute osteoporosis; simple atrophy of bone, usually attributed to disuse; and changes resembling chronic articular rheumatism,—some in cases of painful lesions of the median and tibial nerves, and some in joints, underlying infection and ulcers. Maliwa mentioned a number of cases of atrophy of the bones of the hand, associated with lesions of the ulnar and median nerves, as contrasted to the cases described by Simons.

Simple atrophy was said by Lehmann [11] to be rare in the adult. However, he reported[10] six cases of atrophy in the bones of the hands, and also two cases of atrophy in the calcaneus after injury to the sciatic nerve. Changes resembling chronic articular rheumatism or arthritis deformans were observed by a number of authors, quoted by Bumke and Foerster. Sterling mentioned particularl the type associated with mal perforant, callus formation, microchiria, micropodia, and macropodia. These are of rare occurrence and, according to Lehmann, are always associated with ulceration and infection. For the most part, the greater proportion of instances of changes in bones and joints were associated with partial and usually painful lesions. Their common occurrence in causalgia is noted by Benisty. On the other hand, complete lesions of large trunks of nerves, uncomplicated by vascular or other injuries, infection, or ulceration, were rarely found in association with bone atrophy.

The author was unable to find any recent reports of experiments to determine the effect of denervation upon adult bone. Howell and Tower have described the relation of neural influences upon bone growth and development. For experiments dealing with atrophy of adult bone, one must consult some very old reports, and the conclusions are by no means clear or in agreement. In the often quoted experiments of Schiff, the bones of the paralyzed limb were less voluminous than those on the opposite side, whereas the periosteum of the paralyzed side was thickened. Two months after the operation had been performed on two cats, although the bones were smaller, the medullary cavities were large. Schiff concluded that the immobility of muscles produces atrophy of bone. He found, however, when animals were allowed to survive twelve or eighteen months, that many parts of the bone were thicker than on the normal side.

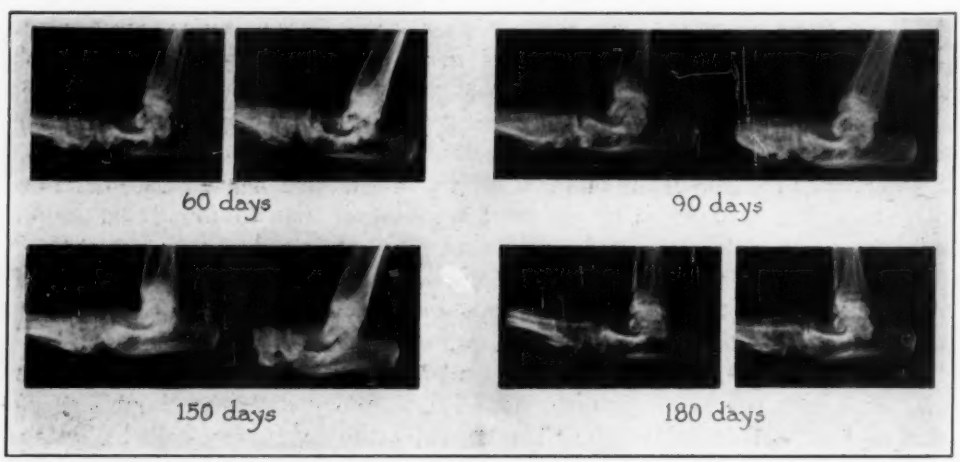

FIG. 1

Roentgenograms illustrate appearance of bones in animals at various times after primary suture.

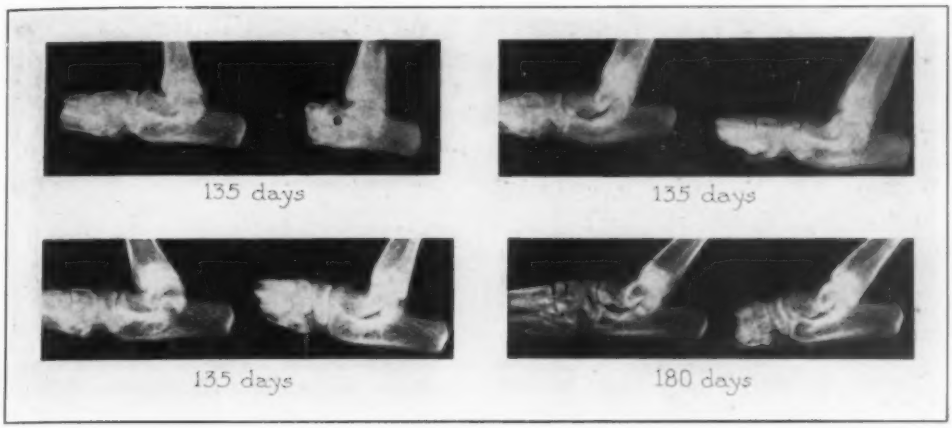

FIG. 2
Roentgenograms taken at various intervals after secondary suture.

Ogle refers to a monograph of Luigi Fasce and Domenico Amato, who, in 1866, stated that a constant reduction of weight took place in the bones of paralyzed limbs after the division of nerves. Ogle also cites Palermo, who, after dividing the brachial plexus of the rabbit, found no changes in the bone.

An experiment upon the effect of electrotherapy on muscle atrophy in cats made available to the author a considerable number of extremities in which denervation had been performed by section of the sciatic nerve, about four centimeters below the sciatic notch. The material may be divided into three groups: first, the animals in which no ulcers developed, either after primary suture or after secondary suture sixty days following section or denervation; second, the animals in which ulcers appeared at some time after surgery; and third, a group of animals whose denervated extremities were immobilized in plaster casts.

In twenty-seven animals, ulcers did not develop after section alone, or section and primary or secondary suture; none showed any changes in the bones which could be demonstrated by roentgenogram. In this group there were twelve animals in which primary suture followed section of the nerve: Three were x-rayed at 60 days, five at 90 days, three at 150 days, and one at 180 days after operation. In addition, there were three animals in which secondary suture followed sixty days after section of the nerve: Two were x-rayed at 135 days and one at 180 days. Finally, there were twelve denervated

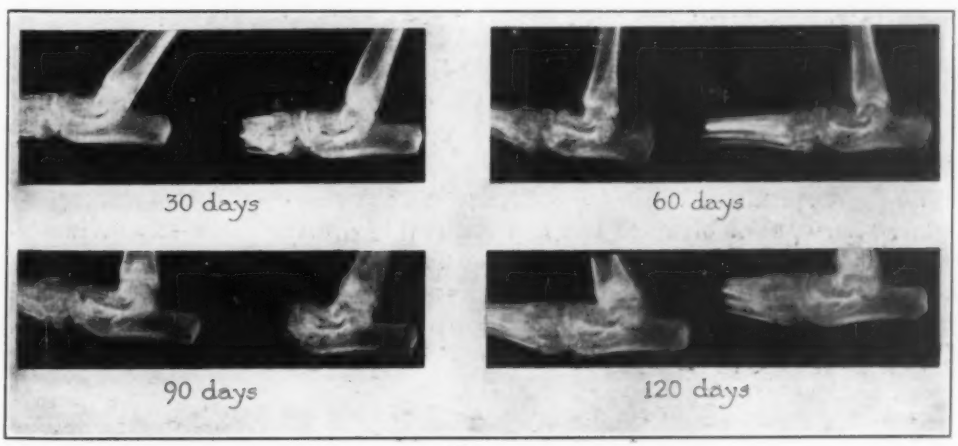

FIG. 3
Roentgenograms taken at various intervals after denervation.

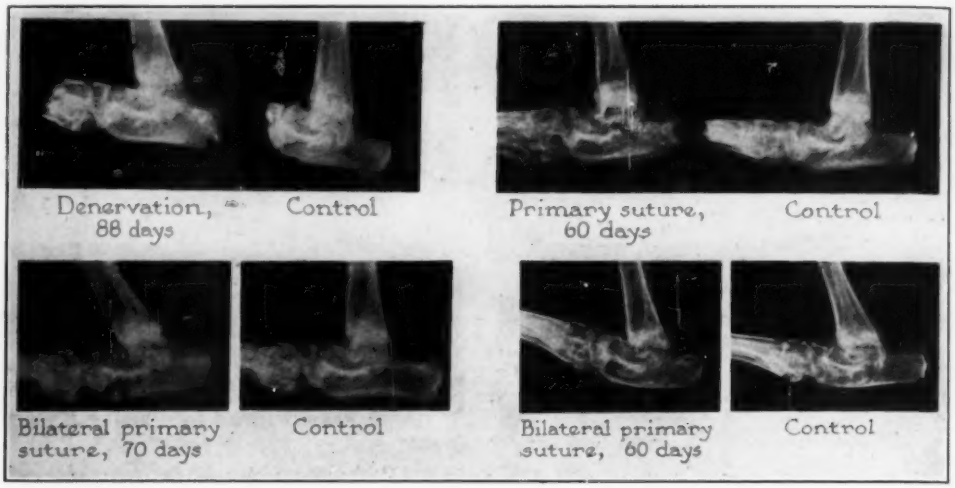

FIG. 4

Roentgenograms at upper left were taken eighty-eight days after denervation of left sciatic nerve; those at upper right were taken sixty days after primary suture of left sciatic nerve. Lower roentgenograms were taken seventy and sixty days, respectively, after bilateral primary suture and immobilization in a cast. Ulcers were present in all.

extremities: Four were x-rayed at 30 days, two at 60 days, three at 90 days, and three at 120 days after section (Figs. 1, 2, and 3.).

Of eleven animals in which an ulcer had developed at some time, some bone change was demonstrated in only one. This was an animal examined 132 days after denervation, and the ulcer of the heel was still present. In five of the other ten, the ulcer had healed; in three it remained unhealed; in one only a denudation remained; in one the ulcer appeared only six days before the animal was sacrificed, ninety days after primary suture.

Roentgenograms were available of eighteen extremities which, after primary suture or denervation, were immobilized in a bivalved plaster cast. Of the eighteen, ulcers developed in eleven. When primary sutures were performed upon both sciatic nerves, one hind extremity was immobilized in a bivalved plaster cast; the other side served as a control. No change in bone could be shown in the extremities in which ulcers had not developed. Of the eleven with ulcers, changes in the bone could be demonstrated in five. In three, the persisting ulcers were large and deep; in two, only scabs were discerned over the heels (Fig. 4).

The changes which were observed consisted of a definite, although slight, atrophy in the tarsal structures. The criteria for determining the existence of bone atrophy were (1) general demineralization and (2) preservation of density in the articular cortex. In one animal, there was local bone destruction of the posterior aspect of the calcaneus (Fig. 4).

Changes in bone were never demonstrable by roentgenogram when ulceration had not occurred at the heel or knee, whether or not the extremity had been immobilized after nerve injury.

The degree of ulceration in the group of immobilized animals was greater than in the other groups, some of which had had bilateral operations. Since those immobilized, but without ulcers, showed no demonstrable change in bone, the change in the animals with ulcer could not be attributed either to disuse or to loss of some "trophic influence" upon bone. It is possible that, when ulcers develop in immobilized extremities, circulatory disturbances may facilitate bone changes.

CONCLUSIONS

These experiments indicate that atrophy of bone does not result from denervation of an extremity, or from immobilization of a denervated extremity. When atrophy of bone

was observed, in rare instances, it occurred as the result of ulceration, overlying the bone and joint. When ulceration occurred in extremities which had been immobilized and denervated, it was more severe than in cases in which the extremity had not been immobilized, and a greater number of cases of bone atrophy occurred.

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CONTRACTURES FOLLOWING EXPERIMENTALLY PRODUCED PERIPHERAL-NERVE LESIONS *

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The development of contractures in certain muscles following peripheral-nerve injuries has been recognized by such authors as Goldstein and Lehmann as a common and dreaded complication. The contractures develop as a result of a variety of causes.

They have frequently been described (by Goldstein, Lehmann, Léri and Roger, Guillain and Barré, and Foerster) in the antagonist of a paralyzed muscle, in which the contracture was due to an adaptive shortening of the actively innervated muscle, because of the lack of opposition by the paralyzed muscle. Foerster [9] called these "*Schrumpfungskontraktur*" and Ranson and Sams applied the term "myostatic contracture". Such a muscle cannot be extended passively without undue force and pain, nor does it yield under narcosis unless excessively severe force is applied. Eventually capsular changes occur, followed by bony fixation.

Other contractures develop in muscles, the nerves of which are irritated or compressed by a foreign body or by scar tissue [9, 13, 17]. Lehmann considered these to be active contractures, due to excessive stimulation of motor fibers.

Painful nerve lesions yield contractures, for example, in the irradiating neuritis of Guillain and Barré and the painful neuritis of Athanassio-Benisty. Lehmann, Guillain and Barré, and Foerster have described contractures in painful neuromata, in which the neuroma produced limitation of motion. In this group the contractures developed as a result of irritation of sensory fibers. Lehmann referred to them as "*neurogene Schonungskontrakturen*" (neurogenic protective contractures). Athanassio-Benisty pointed out the importance of reflex phenomena in the development of such contractures; she cited cases in which the wound did not involve any important nerve, and yielded contractures in muscles which were sometimes on the opposite side of the body.

Babinski and Froment described "*paralysie d'ordre réflexe*", which is known in the English literature as the physiopathic reflex contracture, or congealed hand or foot. It was accompanied by trophic, vasomotor, and thermic changes. Froment has reviewed the more recent investigations, indicating that the phenomena were the result of involvement of sympathetic fibers and were not due to hysteria, as claimed by others. These contractures sometimes followed mild injuries to the extremity, not involving the nerve [19], hence adding support to the concept that, at least in part, they were produced reflexly.

Some contractures are due to fascial shrinkage [16],—for example, in cases in which Dupuytren's contracture followed a lesion of the ulnar nerve. This was supposedly due to involvement of trophic fibers, and it was noted that inflammation surrounding trophic ulcers contributed to this deformity.

Contractures may develop in denervated muscle. Lovett and many others have described the shortening of non-paralyzed muscles in cases of poliomyelitis. More recently, Steindler and his associates have recorded them in 25 per cent. of 200 cases of poliomyelitis, in some of which the contractures were in paralyzed muscles which had been immobilized for from three and one-half weeks to eight months. The limitation of joint movements in these cases is due to muscle shortening, and not to articular or peri-articular changes. Foerster [8] also mentioned that muscle, deprived of efferent nerve fibers, could

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"adapt" itself to a certain degree by shortening when its origin and insertion were approximated, and that this was due in part to the elasticity of such muscle. Tower has shown that, following denervation, a set contracture gradually develops in muscle, which is insidious in onset and is delayed for six to eight weeks. It is not relaxed by general anaesthesia or ischaemia, or in death. However, after re-innervation, even high-grade contractures could be partially reversed. Tower also referred to the fact that contracture does not develop in denervated muscles which are subjected to gravity strain, presumably because the muscle is stretched instead of shortened.

Many investigators, including Goldstein, Lehmann, Athanassio-Benisty, and Foerster[8], have referred to the importance of psychic factors in the development of contractures, believing that immobilization initiated the deformity and that its maintenance was determined by conscious or unconscious influences. Claude stated that in many patients, left to themselves or poorly treated, the abnormal attitude, which was first acquired reflexly because of pain or for protection, becomes fixed, perhaps due to hysterical influences or habit. Similar views were held by others in a discussion of this subject at the Paris *Société de Neurologie* in 1916[3].

Finally, it must be borne in mind that, when a missile produces a nerve injury, it may also damage neighboring tissues. Athanassio-Benisty considered osseous musculotendinous lesions to be one of the important causes of contracture.

Despite the importance of the problems presented by contractures, surprisingly little experimental work has been done in this field. Some investigators have studied the influence of immobilization upon the development of contractures in the presence of the intact or selectively damaged nervous system.

Fröhlich and Meyer stated that immobilization of a denervated extremity of a cat for four or five days did not yield stiffness of the extremity, as would be the case if the nerve were intact. Meyer and Spiegel found that posterior-root section, followed by immobilization for four weeks, yielded no contracture, whereas immobilization of a normal extremity for four days did lead to such a contracture. They believed these contractures to be neuromyogenic, the reflex shortening being the preliminary condition and the myogenic shrinkage following. Spiegel and Shibuya referred to this as "*Ruheversteifung*" (immobilization stiffness).

Riemke claimed that the functional contracture appeared quickly and was followed in two or three days by secondary organic changes in the muscle, connective tissue, tendons, ligament, and joint capsule. The longest period of immobilization he studied was seven days.

Bier opposed the belief that *Ruheversteifung* was dependent upon the intact nervous system only, claiming that it was always seen in the presence of inflammation or injury to the tissues. Hueter, as quoted by Fick, claimed that the prolonged approximation of the ends of a muscle was always followed by "*nutritive Verkürzung*", and that it occurred in paralyzed as well as unparalyzed muscles. Fick studied the shortening of immobilized muscles by actually measuring the fibers. His experiments were of short duration. He agreed with Meyer and Spiegel that the integrity of the reflex arc was necessary for the development of contracture, although he admittedly had contradictory results. For example, in one rabbit he sectioned the brachial plexus, thus denervating the extremity. Then he fractured the foreleg and immobilized the extremity in partial flexion at the elbow. After ten days, he found some shortening of the muscle fibers, which must have developed independently of nerve influences.

Ranson and Sams studied the development of contracture in the gastrocnemius after division of the Achilles tendon. They believe that this "myostatic contracture" is dependent upon the nervous system in its genesis only, and that its persistence is independent of innervation, anaesthesia, or section of the motor nerve. In effect, their experiment showed that contracture will develop in an innervated muscle, if the muscle is unopposed.

The role played by the nervous system in the development of contracture is by no means clear. Most of the experimental work suggests that the nervous system is necessary, but Tower has shown clearly that contracture will develop in six to eight weeks in a denervated muscle. Most of the other investigators failed to find it in immobilized denervated extremities, perhaps because they terminated their observations in from one to four weeks. Furthermore, there is confusion as to what constitutes a contracture, some considering it to be any degree of transient stiffness which opposes easy stretching.

There is no definite investigation in the literature which deals with contractures following peripheral-nerve injuries in circumstances which are analagous to those occurring in the human. In such instances, at least partial immobilization is used. Furthermore, at one time we are dealing with denervated muscles, and at another time with muscles that are being re-innervated. The following report deals with the development and treatment of contractures in the muscles of the cat's leg, following experimentally produced lesions of the sciatic nerve.

MATERIALS AND METHODS

Three types of lesions of the sciatic nerve of the cat's leg were available.

A. Denervation: The sciatic nerve was sectioned at about 4 centimeters below the sciatic notch, and the distal stump was resected for 2.5 to 3 centimeters. One cubic centimeter of absolute alcohol was injected into the central stump.

B. Primary Suture: The sciatic nerve was sectioned, 4 centimeters below the sciatic notch, the ends were immediately approximated, and the epineurium was sutured.

C. Delayed Suture: The sciatic nerve was divided, 4 centimeters below the sciatic notch. The ends were turned back to avoid their reunion. When the suture was made, sixty days later, the retracted and neuromatous nerve ends were first resected for from 3 to 5 centimeters.

In all the sciatic-nerve preparations, the muscles below the knee were paralyzed, so that the foot was flail. In walking, the foot and toes could not be elevated high enough to clear the floor, so that the cat stepped on the dorsum of the toes. In standing, the heel rested on the floor.

In some peroneal-nerve preparations, primary sutures were studied; the level of the section was the same as in the sciatic preparations, except that care was taken not to cut the tibial part of the nerve. This produced drop foot and toes, without paralysis of the plantar flexors of the foot and toes. Such a cat could stand with its heel off the floor.

No form of immobilization was used. The animals were confined to individual cages, eighteen by twenty-four by sixteen inches, where they were usually in a sitting or lying position, with acute flexion at the ankle and knee. They were removed either for daily treatment or for examinations at intervals of five to ten days, when they were permitted to walk around.

METHOD OF EXAMINATION

Only contractures of the following muscles were considered, because they were large palpable muscles: (1) gastrocnemius, (2) tibialis anterior, (3) extensor digitorum longus, and (4) flexor digitorum longus.

One must choose arbitrary but definite positions of the joints involved in examining the extremities, because variations in the degree of flexion or extension in these joints will make the muscles appear to be longer or shorter.

To test the gastrocnemius, the knee is maintained at a right angle. Normally the foot will dorsiflex so as to touch the anterior surface of the leg, executing an arc of 90 degrees. If the arc executed is only 60 degrees, then the measure of contracture of the gastrocnemius is 30 degrees. To test the tibialis anterior, the thigh and leg are maintained in a straight line. With the limb in this position, the ankle extends normally to 180 degrees. Any limita-

tion in extension of the ankle is due to a contracture of the tibialis anterior, the taut tendon of which can be palpated. In testing for the extensor digitorum longus, the knee is maintained at right angles; normally the ankle can then be extended to 180 degrees. Any limitation of this—for example, to 150 degrees—would mean a contracture of the extensor digitorum longus of 30 degrees. To test for the flexor digitorum longus, the knee and ankle are held at a right angle. With the limb in this attitude, the toes normally may be flexed completely, so that the claws touch the plantar surface of the foot, executing an arc of 180 degrees. From the horizontal plane, the toes may extend through an arc of only 90 degrees. Any limitation of this would be a measure of the contracture of the flexor digitorum longus.

With a little experience, one could detect whether the limitation in the range of motion was due to voluntary resistance or to actual muscle shortening. The tendon of the shortened muscle could be palpated and compared with that on the normal side. When a muscle displayed contracture, the animal was examined under anaesthesia prior to sacrifice, to confirm the finding. Then, when the animal was sacrificed, the taut tendons were cut to see if the limitation of joint motion was due to contracture or to arthritic and capsular changes. In all of the animals, it was found that the limitation was due to muscle shortening.

All angles of motion were estimated visually. It is difficult to be sure by this means of estimation that a limitation of motion of only 10 degrees is pathological, so that contractures of less than 15 degrees were eliminated as non-significant.

TYPES OF TREATMENT

A. No Treatment.

B. Massage and Passive Motion: The massage consisted of thirty-six to fifty strokings and twenty-five to thirty-five kneading movements for the entire extremity for a total duration of five minutes daily. Passive motion followed massage. The knee and ankle were moved simultaneously, by alternating flexion of the knee and dorsiflexion of the foot with extension of the knee and plantar flexion of the foot. Alternate flexion and extension of all the toes were performed simultaneously. Each joint was passively moved ten times, care being taken to carry the movement through its full range.

C. Massage, Passive Motion, and Electricity for Five Minutes: To Group B, electrotherapy was added for five minutes daily. Bipolar stimulation to the gastrocnemius was used; the stimulating interrupter key electrode was applied as closely as possible to the origin of the muscle, and the other was an indifferent electrode, close to the insertion of the Achilles tendon. The area of each electrode head was about two square centimeters, and was protected by chamois. Stimulation was given the gastrocnemius by the periodic application of a sixty-cycle alternating current; the current was allowed to flow for three-second intervals and was interrupted for two-second intervals, so as to get twelve contractions per minute. The current strength was adapted in each treatment, so as to produce a prolonged submaximal tetanic contraction with as weak a current strength as possible.

D. Massage, Passive Motion, and Electricity for Fifteen Minutes: This varied from Group C in that electrotherapy was given for a longer interval daily. The sixty-cycle alternating current was interrupted every one and one-half seconds by means of a motor-driven mechanical device, so that forty submaximal tetanic contractions of the muscle were produced each minute for fifteen minutes.

DATA AND DISCUSSION

Before a muscle was accepted as displaying contracture, shortening of the muscle was demonstrable by limitation in the motion of the involved joint and actual palpation of the tendon on stretch. In those animals which displayed contracture at the time of sacrifice, the further criteria were that the contracture must persist under deep narcosis and in death. Furthermore, when the tendons about the joint were severed, complete range of motion in the joint must be possible.

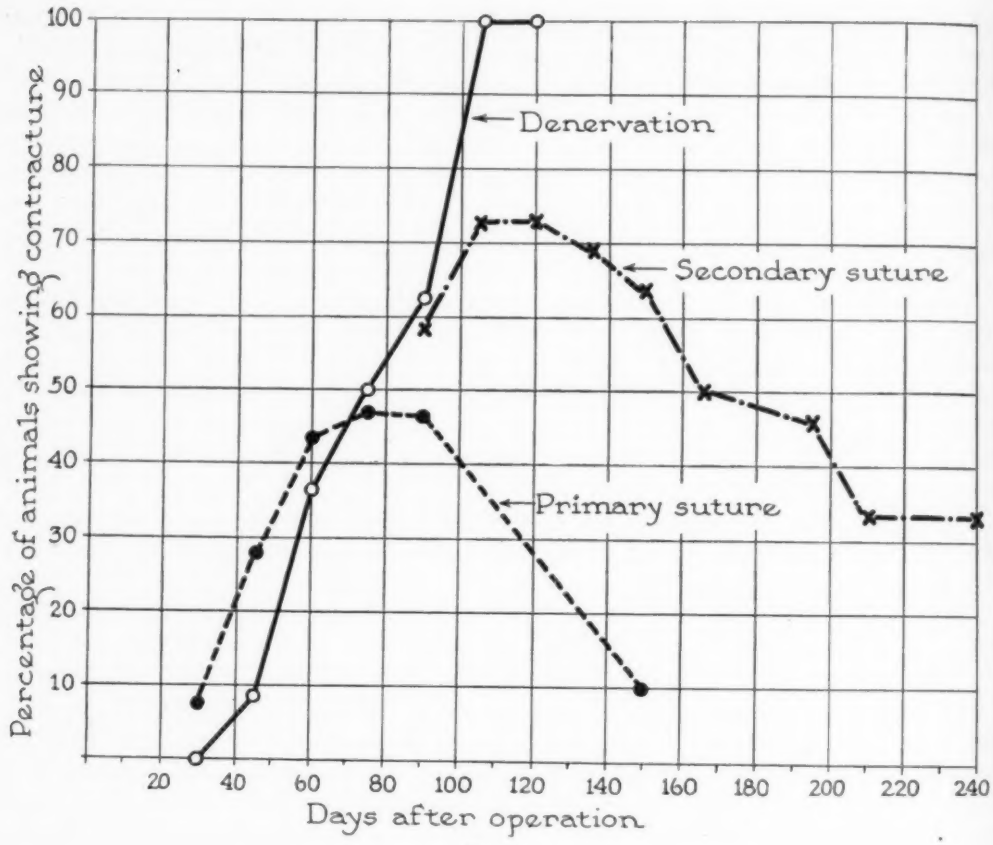

FIG. 1

Frequency of contractures in untreated dorsiflexors of the foot after secondary suture of the sciatic nerve, as compared with frequency after denervation and after primary suture.

A. Denervation Contractures in Untreated Animals

In this series of fifteen animals, of which five survived to 120 days, contractures began to appear in thirty to forty-five days. By 105 days they were present in 100 per cent. of the cases (Fig. 1). They were seen only in the dorsiflexors of the foot. In other experiments where immobilization was used, shortening was evident also in other muscles. It appears that contractures will develop in muscles which are relatively fixed in a shortened state.

The only treatment given these animals was massage and passive motion for fifteen minutes, and it had no beneficial effect. It appeared probable that, if all the animals had been allowed to survive for 120 days, the severity of the contractures in all would have increased to 80 or 85 degrees. These contractures were firm and practically inextensible. They did not yield under nembutal or ether narcosis, or in death. A spot survey of the pathological findings in some of these muscles showed an excessive amount of fibrous tissue, as compared with the normal. The reason for the fixed shortening in the absence of nerve influences is a problem which awaits further study.

B. Contractures after Primary Suture in Untreated Animals

Contractures appear in a large number of the muscles of cats after the nerve has been sectioned and sutured immediately. Of nineteen animals, treated and untreated, contracture was present in sixteen (84.2 per cent.) ninety days after primary suture of the sciatic nerve. The contracture occurred in one or more of the muscles, producing dorsiflexion and plantar flexion of the foot or toes. Eleven animals had contracture of the dorsiflexors of the

foot, seven of the dorsiflexors of the toes, seven of the plantar flexors of the foot, and eight of the plantar flexors of the toes. This high frequency shows the gravity of such a complication after peripheral-nerve injury.

It is evident that contractures develop most frequently in the dorsiflexors of the foot,—that is, either in the tibialis anterior, the extensor digitorum longus, or both. Because of the greater frequency in this muscle group, it was chosen for more extensive study and analysis of contractures in general.

Contractures in Dorsiflexors of the Foot after Primary Suture in Untreated Animals

In Table I are data showing the development of the frequency and severity of this group of contractures. The peak frequency is reached at seventy-five days (Fig. 1). Until this time, the line of ascent is a little more rapid than that for the denervated dorsiflexors of the foot. However, beyond this time, there is a sharp divergence between the two, in that contractures increase after denervation up to 100 per cent. at 105 days; whereas in the cases of primary suture, the peak of frequency is passed after 75 days, and there is a decline to 10 per cent. at 150 days.

In the group with primary suture the peak severity, reached at seventy-five days, does not recede until after ninety days, whereas in the denervation group there is no recession.

For a certain period of time after section and immediate suture of the sciatic nerve, all the muscles below the knee are in a state of denervation. For the dorsiflexors of the foot, the average time of return of function in these animals was sixty-two days, with a minimum of forty-nine days and a maximum of eighty-three days. It is considered by Gutmann, Guttmann, Medawar, and Young that re-innervation takes place some days before function returns. Thus, in animals having primary suture, contractures may develop as a result of the influence of denervation and shortening (which appear as early as thirty to forty-five days); and, secondarily, due to the influence of re-innervation, even before function occurs. This is considered to be true because there are significantly more contractures in animals having primary suture than in denervated animals at forty-five and sixty days after suture (Fig. 1). This is a time when function has not frequently been manifested. However, by seventy-five days it is noted that the denervation contractures surpass the primary-suture contractures in frequency and severity, and it is believed that this is due to the return of function in the group with primary suture. It must be recalled that no immobilization was used in these animals, so that where the function did return, the animals used their extremities more freely to exercise them spontaneously.

At first the contractures were rather elastic and the muscles could be stretched without much pain, so as to produce the complete range of motion at the ankle joint. As the contractures persisted, they became fixed, so that attempts at stretching the muscle were exceedingly painful; and in many instances little, if any, improvement could be obtained in the range of movement of the involved joint. Under nembutal or ether anaesthesia, these contractures were no more reducible with moderate force than they had been without narcosis.

Various correlation studies were made to determine what factors could be considered to contribute toward the development of contracture. There was no relation between the presence of contracture in the dorsiflexors of the foot and the percentage of weight loss in these muscles; nor was there any relation between the percentage of weight loss of the gastrocnemius and the contracture in the dorsiflexors, even though one might anticipate a more marked weight loss in the group with contracture, because then the gastrocnemius might be said to be on stretch.

The presence of fibrillation, ninety days after primary suture, was sought by direct observation of the muscle, with the animal under anaesthesia. Of ten animals showing contractures at this time, one (10 per cent.) showed fibrillation. Of twenty-nine without

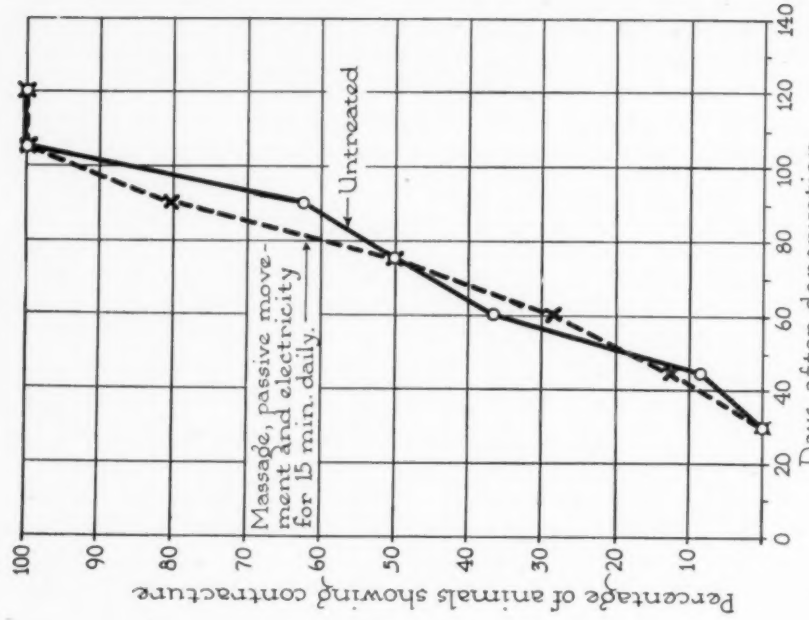

FIG. 3

Fig. 2: Development of contracture in plantar flexors of toes in animals having primary suture, as related to difference in number of days between recovery of function of plantar flexors and that of dorsiflexors of the toes.

Fig. 3: Development of contractures in denervated dorsiflexors of the foot, with and without treatment.

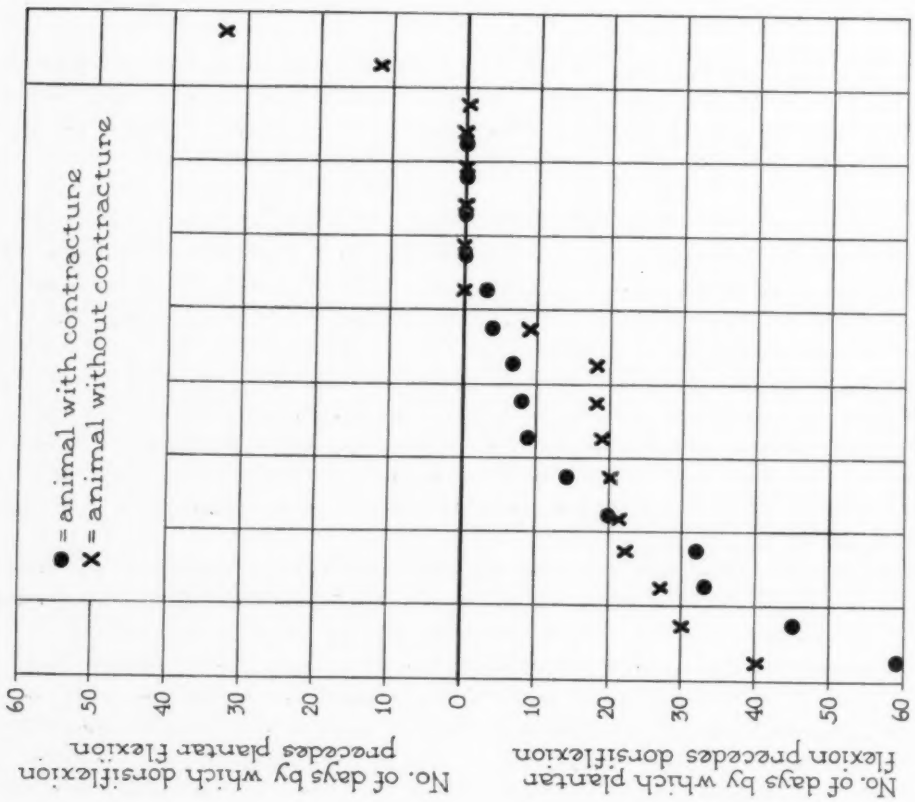

FIG. 2

contractures, seven (24.1 per cent.) showed fibrillation. There was a significantly lower frequency of fibrillation in those muscles with contracture.

No significant difference was seen in the specific gravity of muscles with or without contracture.

Of sixteen animals with ulceration of the heel, four showed contracture of the dorsiflexors of the foot. These data are not sufficient to determine the importance of ulceration in contractures, because most of the animals with serious ulcer were discarded.

In a selected group of twenty-nine animals which survived ninety days after primary suture, it was found that the development of contracture was not related to the time of recovery of function in the paralyzed muscles. The average time for recovery of function in the contracture group was sixty-one days, as compared with sixty-three days for those without contracture.

After sciatic-nerve section, opposing muscles regained function at different times. The longer the difference in time between the recovery of opposing muscles, the more likely was the development of a contracture in the muscle which recovered first (Fig. 2). Of fifteen animals with contracture of the plantar flexors of the toes, there was none in which function returned to the dorsiflexors first. In four, function returned simultaneously to the dorsiflexors and plantar flexors; and in the remaining eleven (73.3 per cent.), recovery of the plantar flexors preceded that of the dorsiflexors. In eighteen animals without contracture in the plantar flexors of the toes, there were only ten (55.5 per cent.) in which recovery of the plantar flexors preceded that of the dorsiflexors; and in most instances it was to a less significant extent than in the animals with contracture. In six, recovery of function in both groups was simultaneous; and in two animals, recovery of function in the dorsiflexors preceded recovery in the plantar flexors of the toes. However, the return of function in the opposing muscles in a non-immobilized animal will tend to dissipate a contracture quickly.

In a few animals, in which either the dorsiflexors or the plantar flexors of the foot had been denervated alone, contracture developed in the muscle group which retained its innervation. This is due to the principle just described, in which opposing muscles recover function at different times.

C. Contractures after Delayed Suture in Untreated Animals

In a selected group of fifteen cats, sciatic-nerve suture was delayed for sixty days. At ninety days after suture, 100 per cent. showed contracture in one or more of the muscles producing dorsiflexion or plantar flexion of the foot and toes; this is even greater than the figure of 84.2 per cent. for animals ninety days after primary suture. Thirteen had contracture of the dorsiflexors of the foot, thirteen of the dorsiflexors of the toes, eleven of the plantar flexors of the toes, and only three of the plantar flexors of the foot. For purposes of analysis of a larger amount of material and for comparison with the studies on animals with primary suture, the development of contractures in untreated animals was confined to the dorsiflexors of the foot,—that is, a contracture in either the tibialis anterior or the extensor digitorum longus, or both.

The frequency of contractures of the dorsiflexors of the foot is certainly greater after delayed suture (72.7 per cent.) than after primary suture (47.1 per cent.). It is considered that the longer period of denervation favors this outcome (Table II).

The plotting of the days after operation for the animals with delayed suture (Fig. 1) was taken as the number of days after section of the sciatic nerve, which was sixty days before the nerve was resutured. This was done because actually, during this sixty days, the muscles were in a state of denervation; and any factor operating in the development of contracture in these muscles is equally as important as in those muscles which were denervated and not allowed to regain their innervation. Thus it will be seen that the first point for secondary suture is plotted at ninety days, which is actually only thirty days after

TABLE I

ANALYSIS OF CONTRACTURES OF DORSIFLEXORS OF THE FOOT AT VARYING TIMES AFTER PRIMARY SUTURE OF THE SCIATIC NERVE WITH DIFFERENT TYPES OF TREATMENT

Days after Suture	No Treatment			MPM			MPME—5 min.			MPME—15 min.		
	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)
30	26	7.7	20, 45	25	0	0	15	0	0	20	0	0
45	25	28.0	20, 20, 25, 30, 25, 35, 40	24	8.3	15, 30	15	0	0	17	0	0
60	23	43.5	15, 20, 20, 20, 30, 35, 40, 45, 45, 45	23	21.7	20, 20, 30, 30, 50	14	14.3	15, 20	13	38.4	20, 20, 35, 40, 40
75	17	47.1	15, 20, 30, 35, 35, 35, 40, 40	15	20.0	15, 20, 20	10	30.0	20, 40, 50	12	41.6	15, 20, 30, 35, 40
90	15	46.6	15, 20, 30, 35, 40, 40, 60	13	15.4	20, 20	10	40.0	15, 20, 40, 45	11	45.4	20, 25, 40, 45, 45

MPM = Massage and passive motion.
MPME—5 min. = Massage, passive motion, and electricity for five minutes.
MPME—15 min. = Massage, passive motion, and electricity for fifteen minutes.

TABLE II

ANALYSIS OF CONTRACTURES OF THE DORSIFLEXORS OF THE FOOT AT VARYING TIMES AFTER DELAYED SUTURE OF THE SCIATIC NERVE WITH DIFFERENT TYPES OF TREATMENT

Days after Suture	No Treatment			MPM			MPME—5 min.		
	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)	No. of Animals	Contractures (*Per cent.*)	(*Degrees*)
30	12	58.3	15, 20, 25, 45, 60, 70, 70	10	20.0	15, 50	7	28.5	30, 50
45	11	72.7	15, 20, 30, 45, 45, 70, 70	9	33.3	20, 30, 50	7	28.5	30, 50
60	11	72.7	20, 20, 20, 30, 35, 40, 60, 80	10	60.0	15, 40, 40, 55, 60, 60	6	50.0	20, 30, 45
75	13	69.2	20, 20, 20, 30, 40, 45, 60, 70, 70	10	50.0	25, 35, 45, 45, 60	6	50.0	20, 20, 45
90	11	63.6	20, 20, 30, 45, 60, 60, 70	10	70.0	40, 45, 50	7	71.4	20, 20, 20, 45, 45
105	12	50.0	30, 30, 30, 35, 45, 55	11	54.5	20, 20, 20, 30, 40, 45	7	71.4	20, 20, 20, 40, 45
135	13	46.1	20, 20, 30, 30, 40, 65	11	45.4	20, 25, 35, 40, 45	7	71.4	20, 20, 20, 45, 60
150	6	33.3	30, 35	4	25.0	40	3	33.3	70

MPM = Massage and passive motion.
MPME—5 min. = Massage, passive motion, and electricity for five minutes.

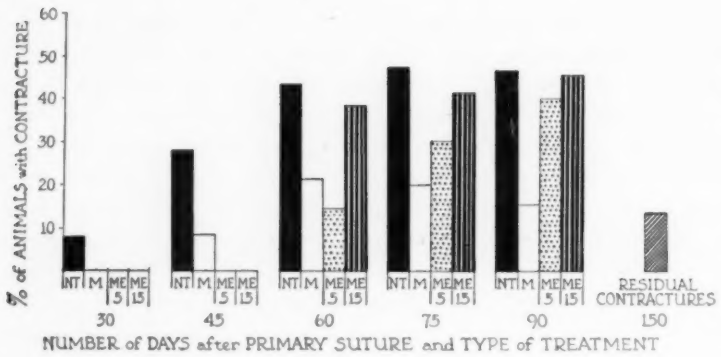

FIG. 4

FIG. 4

Frequency of contractures in the dorsiflexors of the foot at various intervals after primary suture of the sciatic nerve, various types of treatment being used.

NT = No treatment.
M = Massage and passive motion.
ME 5 = Massage, passive motion, and electrotherapy for five minutes.
ME 15 = Massage, passive motion, and electrotherapy for fifteen minutes.

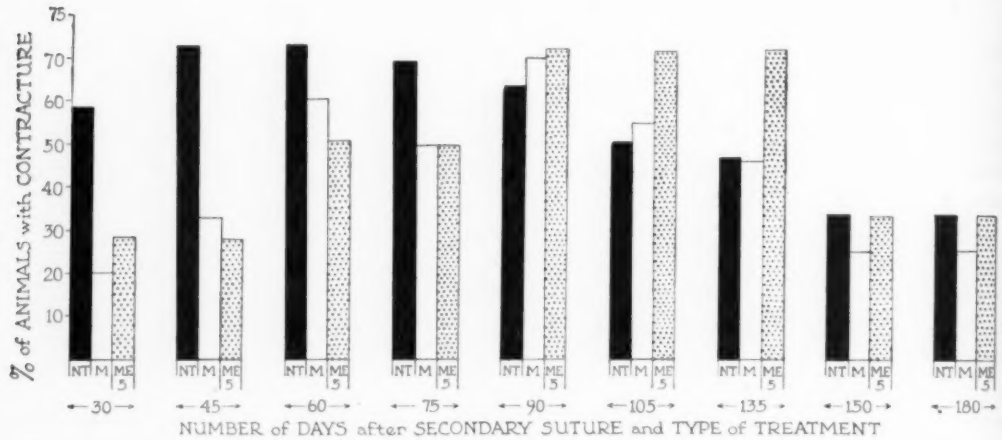

FIG. 5

Frequency of contractures in the dorsiflexors of the foot at various intervals after delayed suture of the sciatic nerve, various types of treatment being used.

suture. Since at this time it was impossible for the axon to regrow into the muscle, we are still dealing with a denervated muscle; and it may be seen that the curves for the delayed and denervated groups approximate each other. The recession from the peak frequency in the animals with both primary and secondary suture takes place spontaneously, as recovery of function occurs. There are more frequent residual contractures after secondary suture (33.3 per cent.) than after primary suture (10 per cent.) at 150 days after suture. A similar sequence of events is evident in reference to the severity of contractures. These facts are just cause for urging early operation after severance of a peripheral nerve.

D. Effect of Treatment upon the Development of Contractures of the Dorsiflexors of the Foot

The need of physiotherapy early after the occurrence of peripheral-nerve lesions has been amply recognized. Much has been said about the necessity of immobilizing the paralyzed muscle in a shortened position to prevent overstretching of the muscle fibers. Highet recently pointed out the value of therapy twice daily, and claimed that all involved joints should be exercised passively through their complete range of motion. He believed that transient stretching of a denervated muscle was beneficial in preventing contractures.

In a series of eleven denervated animals treated with massage, passive motion, and electrotherapy for fifteen minutes, there was no perceptible difference in the rate of development of contractures in the dorsiflexors of the foot as compared with the untreated group (Fig. 3).

In the animals having primary suture, there was no doubt but that massage and passive motion had definite value in decreasing the frequency and severity of contractures, as compared with the untreated group (Table I and Fig. 4). The peak frequency of 21.7 per cent. was reached at sixty days in the treated group, as compared with 47.1 per cent. at seventy-five days in the untreated group. The recession of contractures was better with this treatment.

In the group with delayed suture, massage and passive motion did not have such an obviously beneficial effect (Table II and Fig. 5). Although contractures occurred almost as frequently with this treatment (70.0 per cent.) as without it (72.7 per cent.), retardation of the peak frequency for forty-five days is valuable, because it brings the muscle into the period of recovery of function at which time the contracture can be dissipated more easily. The beneficial effect of massage and passive motion on the severity of delayed-suture contractures was more apparent than after primary suture.

The recession of contractures following primary suture could not be analyzed, because most of the animals were sacrificed at ninety days. After delayed suture, the contractures in untreated and treated animals recede at about the same rate. The explanation for this becomes apparent when we recall that, after recovery of function, these animals, which were not immobilized, were actually treating themselves by walking. The short period of massage and passive motion would thus be insignificant in comparison with this spontaneous form of active exercise.

The validity of the addition of electrotherapy to massage and passive motion has frequently been the cause of debate in the treatment of peripheral-nerve lesions. The discussion has usually concerned itself with its value in preventing atrophy or in producing an earlier or better return of function. The only two references which were found to deal with electrotherapy and contractures were simply statements of clinical experience. Elmslie, in a symposium on the treatment of peripheral-nerve injuries, mentioned that he saw many contractures and deformities, even with electrotherapy. Goldstein cautioned that electrotherapy may do more harm than good, and that there is a time when it can favor the development of contractures. Although he did not elaborate, he claimed that in a muscle with a tendency toward the development of contracture, electrical treatment will increase the contracture to a marked degree.

In the animals with primary suture, it was at least suggestive that, in the early postoperative period, electrical treatment has some influence in retarding the development and decreasing the severity of contractures (Fig. 4). The contractures did not appear until sixty days after suture, whereas in the groups without treatment and with massage and passive motion, they appeared earlier. From sixty days on, electrical therapy appeared to have a deleterious effect upon the influence of massage and passive motion, since the more intense the electrotherapy, the more closely did the frequency and severity of contractures approximate those in untreated animals. The fact that the peak with electrotherapy was reached later than in either of the other groups further suggests its deleterious influence, because the longer it was used, the more frequent and severe were the contractures. It will be recalled that electrical stimulation was given to the gastrocnemius and, in treatment, a brisk plantar flexion of the foot was obtained. Due to spread of the current, many of the animals showed a preliminary dorsiflexion of the foot, followed by the more pronounced plantar flexion. Thus it is probable that the dorsiflexors of the foot also received electrical treatment.

In a group of twelve animals, bilateral primary suture of the peroneal nerves was done at the same level as the total sciatic-nerve sections and sutures. The animals were permitted free mobility in their cages, and were allowed to survive eighty days. The left leg was treated only with electricity, as previously outlined, and the right leg was untreated. This type of therapy definitely contributed to the development of contractures in the unparalyzed antogonists of paralyzed muscles: In all but one (91.7 per cent.), tightness or

contracture of the gastrocnemius developed. Definite fixed contracture developed in seven (58.3 per cent.), and most of the contractures appeared late. In the untreated extremities a "tightness" or contracture appeared in the unparalyzed antagonist in only 33.3 per cent. of the cases, and was of transient duration. It is difficult to understand why electrotherapy should do this, but the answer may be found in histological studies.

The severity of contractures after primary suture was also aggravated by electrotherapy. Those animals treated with massage, passive motion, and electricity for five minutes showed more contracture than those treated with massage and passive motion alone. The amount of contracture, according to percentage of animals, for those treated by massage, passive motion, and fifteen minutes of electrotherapy, was practically identical with that for the untreated group at ninety days.

In the delayed-suture group, insufficient animals were treated with massage, passive motion, and electricity for fifteen minutes, so they were omitted. In those treated for five minutes, the influence of electrotherapy was somewhat similar to that in the animals with primary suture (Fig. 5). The development of contractures in this group kept pace with the group treated only with massage and passive motion. Electricity, even for five minutes, seemed to retard the recession of contractures beyond ninety days after suture, because the peak of 71.4 per cent. was maintained until 135 days; at that time, untreated animals had a frequency of 46.1 per cent., and animals treated with massage and passive motion had a frequency of 45.4 per cent. Beyond 135 days, all three groups had approximately the same frequency (25 to 33.3 per cent.).

Influence of Treatment upon the Reversibility of Contractures

It was found that treated muscles were more pliable, even when showing contracture. With moderate or mild force, they could be stretched so as to produce the full range of motion, with the production of relatively little pain.

In a series of twenty-two primary animals with contractures of the dorsiflexors of the foot, the contracture had entirely disappeared in five (22.7 per cent.) by the time they were sacrificed. Of these five, there were three untreated and two treated animals. Similarly, in a series of twenty-seven animals with delayed suture, which showed contracture of the dorsiflexors of the foot at some time during life, nine had lost their contracture by the time they were sacrificed. Of these, four were untreated and five were treated. Contractures can reverse themselves, regardless of treatment.

Influence of Immobilization on the Development of Contractures

An attempt was made to obtain a series of cats which had had various forms of treatment, plus immobilization. The immobilization was produced by a plaster cast, which encased the animal from the mid-thorax downward. Some of the experiments were unilateral: One lower extremity only was encased in a position with both the knee and the ankle at right angles, whereas the other lower extremity was permitted to be free. Other experiments were bilateral, so that both lower extremities and the body were encased in plaster. This cast was so constructed that the posterior portion of it could be removed daily for treatment or examination of one or both legs. The posterior portion of the cast could then be replaced and strapped into place, so that effective immobilization continued. In spite of numerous attempts with various types of casts, ulceration invariably developed, either at the knee or ankle or at both sites, after about two or three weeks. Some of these animals could be nursed along, so that they survived for a period of time, as will be indicated later, without being in too bad a condition.

Although the number of animals in this series was not great, the results shed some light upon the development of contractures. In those animals which were immobilized without having had nerve section, no contractures developed after immobilization for as long as ninety days. This is difficult to reconcile with the statements of various authors

that contractures, persisting under narcosis and in death, could be produced after immobilization for perhaps one or two weeks. However, it is more in agreement with the clinical experience in those cases without bone or joint disease.

Denervation, followed by immobilization for ninety days, permits the development of contractures in all muscle groups. Contracture did not develop in one untreated animal with primary suture, which survived thirty-two days; but did develop in two others which survived sixty and ninety days, respectively.

Similarly, in the primary animals with bilateral immobilization, contractures began to appear at twenty-eight days; and by sixty days they became universal in the dorsal and plantar flexors of the foot, regardless of electrotherapy. It appears to take about thirty days for contractures to develop after primary suture and immobilization, but within the next thirty days they develop frequently and rapidly. Because of the scanty material, one cannot say how much of this is due to denervation and how much to re-innervation. However, it is obvious that immobilization greatly increases the frequency of development of contractures.

CONCLUSIONS

1. Contractures do not develop in the normal extremity of a cat, immobilized for as long as ninety days; but do develop in denervated muscles, if they are maintained in a shortened position for from forty-five to 105 days.

2. After primary suture of the sciatic nerve in cats, contractures occur in 84.2 per cent. of cases in one or more muscles below the knee, and after delayed suture in 100 per cent. of cases, after ninety days.

3. Contractures occur most frequently in the dorsiflexors of the foot of the cat after section and suture of the sciatic nerve. They are less severe, less frequent, and less persistent after primary suture than after delayed suture in untreated animals. Residual contractures are more frequent after delayed than after primary suture.

4. Massage and passive motion definitely decrease the frequency and severity of contractures of the dorsiflexors of the foot, which occur after primary suture. After delayed suture, this type of treatment seems only to retard the development of the peak frequency of contractures for forty-five days, but it undoubtedly decreases their severity.

5. The addition of electrotherapy to massage and passive motion delays the appearance of contractures for a longer period after primary suture than does the latter alone. Thus electrotherapy may have some beneficial influence in the early postoperative period. The longer the period of electrotherapy, the more closely do the frequency and severity of contractures approximate those in untreated animals. Electrotherapy favors the development of contractures in the unparalyzed antagonists of paralyzed muscles. It seems to retard the dissolution of contractures which occur after delayed suture.

6. Spontaneous movement of the animal after recovery of function can serve to dissipate a contracture, no matter what influences tend to preserve it.

7. Contractures are more frequent after section and suture of the sciatic nerve of cats, if the extremity is immobilized, than if the extremity is permitted to be free.

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DISLOCATION OF THE PISIFORM

BY E. WILLIAM IMMERMANN, M.D., CHICAGO, ILLINOIS

Dislocation of the pisiform bone is a rare entity. It is still more rare to have chronic recurrent dislocation of the pisiform. The case to be reported is believed to be the first complete description of such an entity. It warrants mention in view of the resulting disability, and because of the difficulty in diagnosis.

By 1901, Fergusson, Erichsen, Gras, Buchanan, Barois, Oberst, and Eigenbrodt had reported cases of dislocation of the pisiform. Practically all of the cases antedated the discovery of roentgen rays. Cohen states that Van der Donck, in 1899, reported a case of dislocation due to a fall, in which the roentgenogram "showed the pisiform between the radius, semilunar and cuneiform". The bone was removed, and marked improvement of the disability resulted. Cotton, in 1910, reported a case in which a painful mobile pisiform followed a fall; the bone clicked with motion. There was also some sensory disturbance of the ulnar nerve. No mention was made of a roentgenogram or of reduction, and the case was lost sight of after several weeks of immobilization.

Ozenne, in 1911, reported two cases. In the first case, the injury occurred secondary to lifting. No roentgenograms were taken. Clinically, the pisiform was palpated at the styloid process of the ulna, creating a depression at the normal site of the pisiform. The dislocation was not corrected by two weeks of immobilization. After six months, there was some limitation of adduction. In the second case, seen ten years after the injury, the dislocation had also resulted from lifting.

Cohen, in 1922, reported the case of a boy who dislocated his pisiform by a fall upon his hand. In addition, he received a backward displacement of the radial epiphysis. The pisiform was palpated at a higher level and was abnormally mobile. A gauze pad, pulling distally, was strapped over the pisiform, and the wrist was placed in flexion. Reduction of the pisiform was not determined, since the roentgenogram was not satisfactory for interpretation. After fifteen days, function was returning rapidly; but thereafter the patient failed to report.

Mather, in 1924, reported a case in which, after the patient had lifted a weight, something "gave" in the wrist. Mather stated that the roentgenograms showed the pisiform to be between the triangular bone and the ulna. The wrist was splinted in full flexion for three weeks. No mention was made of roentgenograms after reduction, or of manipulation to reduce the dislocation before application of the splint. Since the patient continued to have pain, the pisiform was removed. Complete return of function occurred in five weeks.

Wagoner, in 1930, reported a dislocation of the pisiform secondary to a fall on the hand. There were also fractures of the same area, involving the head of the radius and the styloid process of the ulna. Wagoner stated that roentgenograms showed the pisiform to have rotated through its upper pole, downward and inward. The dislocation was reduced under general anaesthesia and by means of fluoroscopy, and the wrist was placed in a cock-up splint. The result was excellent in five weeks.

The pisiform bone lies in the proximal row of carpal bones and articulates dorsally with the triangular bone. The volar surface is roughened, offering attachment to the transverse carpal ligament, abductor digiti quinti, and flexor carpi ulnaris. The latter prolongates to form the pisohamate and pisometacarpal ligaments. The volar branch of the ulnar nerve and the ulnar artery pass lateral to the pisiform.

Dislocation of the pisiform may result either from a direct injury or from muscular violence. In the cases reported, the ratio was two to one in favor of muscular force as an etiological agent. This force in all instances was manifested as the patient was in the

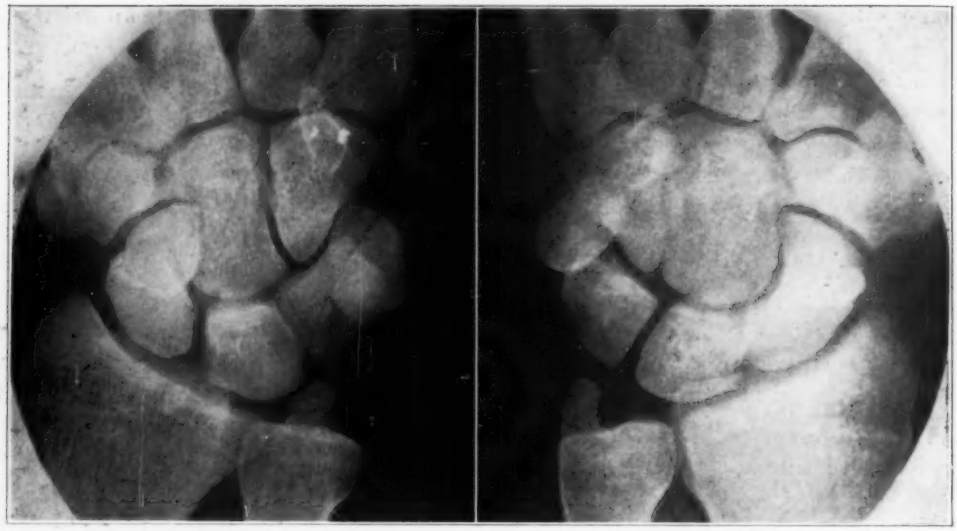

FIG. 1-A FIG. 1-B

Fig. 1-A: Anteroposterior view of normal right wrist.
Fig. 1-B: Anteroposterior view of left wrist, demonstrating dislocated pisiform.

FIG. 2-A FIG. 2-B

Fig. 2-A: Lateral view of right wrist, demonstrating normal position of pisiform.
Fig. 2-B: Lateral view of left wrist, demonstrating dislocation of pisiform.

process of lifting a heavy object. Perhaps this bone has a tendency to become dislocated, since it was never intended to function in man as part of the mechanism of lifting. In man the hand is no longer a means of locomotion and, therefore, the carpal bones have undergone changes to conform to the new functional demand. Bizarro points out that the pisiform, which is the heel of the hand in the non-aquatic vertebrate, has become a regressive structure in man. An additional factor which should be taken into consideration is that one invariably flexes the wrist while lifting, which tends to draw the pisiform away from the triangular bone.

Clinically, following a dislocation, the pisiform is painfully displaced from its normal site, leaving a depression. Flexion and adduction may be painful, and there may be exaggerated mobility of the bone. The diagnosis can be confirmed by roentgenograms, with

the ulnar side of the wrist placed against the plate in about 15 degrees of supinated rotation. One must bear in mind that in an acute or recurrent dislocation the bone may return to its normal position, producing a negative roentgenogram. In the chronic case, where the patient complains of pain in the volar aspect of the wrist with a sensation of "giving way" upon lifting, duplication of the etiology may confirm the supposed diagnosis, as demonstrated in the case report.

CASE REPORT

The patient, a nineteen-year-old white male, entered the office with the complaint that he was unable to do heavy lifting, because of pain in the volar aspect of his left wrist "when something jumped out of place". When this happened, he stated, working the wrist up and down caused it "to jump back into place".

He experienced repeated episodes for nearly six years, dating back to an episode of acute pain in the wrist when he was lifting a heavy piece of lumber. A friend "snapped" his wrist, which seemed to correct the difficulty. He returned to work with moderate pain in the wrist, which subsided in time.

In the past four years he had been examined by two physicians, but nothing was found clinically or by roentgenogram, and the patient was discharged without treatment. During the course of such observation his wrist was put in a cast for three weeks to relieve a possible tenosynovitis.

Quite discouraged, he entered the office with this complaint. Clinically, the examination was essentially negative. He was asked if he could make this "something" jump out of place. He forcibly flexed and dorsiflexed while deviating his hand ulnarward. After fifteen minutes he suddenly exclaimed: "There, it happened again". Roentgenograms (Figs. 1-A, 1-B, 2-A, and 2-B) were taken, confirming the clinical impression. Pain was present across the volar aspect of the wrist, especially in the area of the pisiform. The bone was displaced distally, leaving a depression at its normal site. The wrist could be gently flexed and dorsiflexed without the bone being relocated. The patient forcibly flexed the wrist and reduced the displacement. It was found impossible to dislocate it with direct forceful digital pressure, even though there was a moderate degree of mobility of the bone.

FIG. 3

Lateral view, after removal of the pisiform.

The pisiform was shelled out surgically (Fig. 3) through a transverse incision directly over the bone. The space occupied by the pisiform was closed so as to maintain the continuity of the flexor carpi ulnaris with the pisohamate and pisometacarpal ligaments. Four weeks after operation the patient resumed heavy labor; he had no discomfort, and a full range of motion was possible. He was seen six months later; at that time the result was perfect.

TREATMENT

In an acute dislocation with the wrist in flexion, the bone should be manipulated into place. An anterior molded plaster splint should be applied, with the wrist in dorsiflexion (30 to 40 degrees) and radial deviation for eighteen to twenty-one days. This position rigidly fixes the pisiform. In an acute case where the disability remains after splinting, or in a chronic case, surgical excision is recommended.

SUMMARY

1. Dislocation of the pisiform is rare. Volar pain in the wrist with the sensation of "something going out of place" may indicate a dislocating pisiform.

2. Dislocation of the pisiform is caused either by muscular violence or direct injury.

3. The pisiform is a regressive structure in man, but forms the heel of the hand in the non-aquatic vertebrate.

4. In acute cases of dislocation which do not respond to splinting, and in chronic

cases, surgical excision is indicated. Removal of the bone in no way interferes with the normal function of the wrist.

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COMPRESSION OF THE SPINAL CORD DUE TO DIRECT EXTENSION FROM A TUBERCULOUS PULMONARY ABSCESS

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Compression of the spinal cord by a tuberculous abscess in conjunction with tuberculous spondylitis is a well-known entity. The usual beginning of such a lesion is a focus in the body of one or more vertebrae, with the resultant abscess formation, which protrudes posteriorly through the intervertebral disc and causes pressure on the posterior longitudinal ligament. The abscess may also perforate this ligament and gain access to the canal.

Tuberculous spondylitis has always been considered a secondary lesion, due to a lymphatic extension or to a blood-borne infection. Tuberculous abscesses arising from the upper thoracic spine have frequently been known to rupture into the pleural cavity or into the lung. While tuberculous joints may become involved by direct extension from adjacent tissues, such as infected tendon sheaths or bursae, direct extension to the spinal canal and its contents from an adjacent focus is exceedingly rare.

A comprehensive review of the literature has disclosed very little mention of such a process. Alpers and Palmer reported one case in 1934, which was practically identical to the first case in this paper. Eaton and Rogers, in 1938, also reported one case of transverse myelitis, caused by pressure from a lung abscess. With the exception of these instances, no reports have been found.

The following two cases of compression of the spinal cord as a result of direct extension from a pulmonary lesion, without the usual picture of Pott's disease, presented a true diagnostic problem. It is usually felt that a destruction of the pedicle shadows, as seen in the roentgenograms of the first case, is the result of a tumor of intraspinal origin, rather than the result of an infectious lesion from without.

CASE 1 (No. 1753). R. A., a thirty-year-old white male, was admitted to the sanatorium on December 9, 1943. He stated that in July 1942 he had suffered an attack of pleurisy on the right side. Since that date, he had been forced to seek a lighter type of work. In July 1943, he consulted a physician, who made a diagnosis of tuberculosis of the right lung. On July 29, 1943, a right pneumothorax was induced, but the patient's condition became progressively worse. On November 17, 1943, he noticed a sense of weakness in the left leg, associated with numbness, which became progressively worse. About two weeks later, he noticed similar symptoms in the right lower extremity. On admission, the examination revealed complete spastic paralysis of both lower extremities. The deep reflexes of the upper extremities were hyperactive, and the knee jerks and ankle jerks were each four plus. The Babinski sign was present bilaterally, and there was sustained ankle clonus on both sides. The abdominal and cremasteric reflexes were absent. There was some hypoaesthesia below the nipple line, with tenderness at the level of the spinous processes of the third and fourth thoracic vertebrae.

The laboratory findings showed the Kahn reaction to be negative. The sedimentation rate was nineteen millimeters in fifteen minutes and twenty-six millimeters in thirty minutes. The stomach washings were positive for the tubercle bacillus. Otherwise, the routine tests were normal. A spinal puncture revealed clear fluid with an initial pressure of twenty-four centimeters. There was no rise or fall of pressure after compression of the jugular veins.

Roentgenograms showed destruction of a portion of the third and fourth ribs on the right, posteriorly, at the juncture with the spine, and a destruction of the pedicle shadows of the third and fourth thoracic vertebrae on the right (Fig. 1-A). However, there was no roentgenographic evidence that this patient had true Pott's disease.

It was obvious that a destructive lesion of some form was present at the level of the third and fourth thoracic vertebrae. An exploratory operation, performed shortly after admission, showed partial destruction of the lamina of the third thoracic vertebra on the right side. Some of this tissue was removed from between the second and third laminae for frozen-section study. This tissue was typical tuberculous granulation tissue. It was apparent that the patient had a tuberculous lesion, involving the spinal cord.

The patient died on February 27, 1944, and a complete autopsy was performed. The essential findings were a cavity in the base of the right upper lung lobe, extending posteriorly through both pleural layers into the body wall. A tuberculous caseous tract followed along the third and fourth ribs, destroying a portion of each of these ribs and also the pedicles of the third and fourth thoracic vertebrae on the right side. It extended through the intervertebral foramen into the spinal canal and enveloped the spinal cord (Fig. 1-B). The cord was irregularly compressed by a caseous mass which invaded the dura. The cord above and below this lesion was normal.

These findings demonstrate very clearly that a tuberculous transverse myelitis can occur as a result of direct extension from an adjacent focus.

CASE 2 (No. 1981). J. L., a twelve-year-old Mexican boy, entered the sanatorium on June 2, 1944, because of pulmonary tuberculosis. Shortly after admission a large cold abscess developed on his back to the right of the mid-line, at the level of the upper thoracic spine. The pus was aspirated on frequent occasions, and the tubercle bacillus was found in this material. Repeated roentgenograms of the thoracic spine failed to show any evidence of destruction of the vertebrae (Fig. 2-A), as is characteristic of tuberculous spondylitis.

In March 1946, the patient began to show signs of paraplegia. The lower extremities eventually became completely paralyzed, with an increase in the deep reflexes and an absence of the superficial reflexes. The Babinski sign was present. There was loss of sensation below the level of the fifth thoracic vertebra. The patient died on June 12, 1946, and again a complete autopsy was performed.

The essential autopsy findings were as follows: The left lung was free in the pleural cavity; the right lung was adherent throughout, especially at the apex, where there was a dry, caseating subpleural sinus

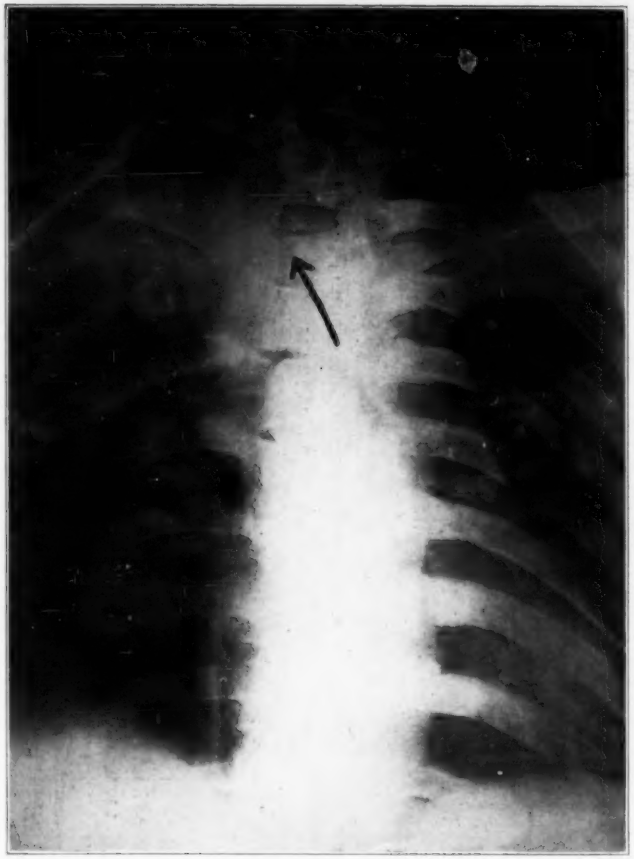

FIG. 1-A

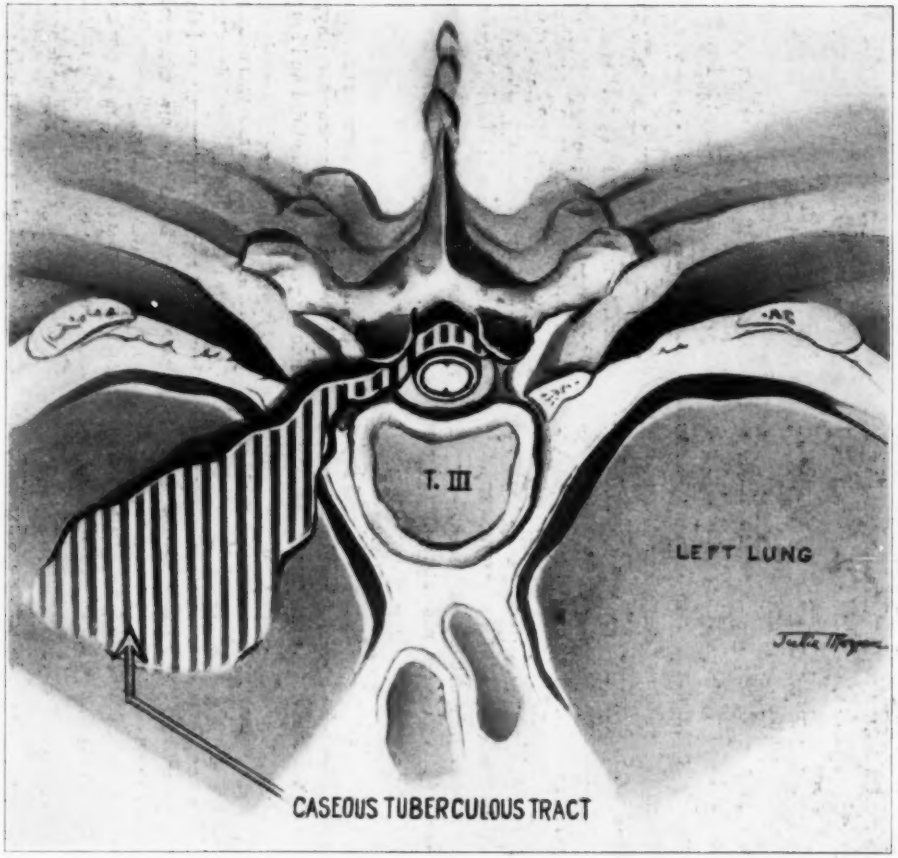

FIG. 1-B

Fig. 1-A: Case 1. Showing destruction of a portion of the third and fourth ribs on the right, and the pedicle shadows of the third and fourth thoracic vertebrae on the right.

Fig. 1-B: Diagram showing tuberculous cavity in right lung, which has perforated through the pleura and extended along the body wall and into the spinal canal by way of the intervertebral foramen.

FIG. 2-A

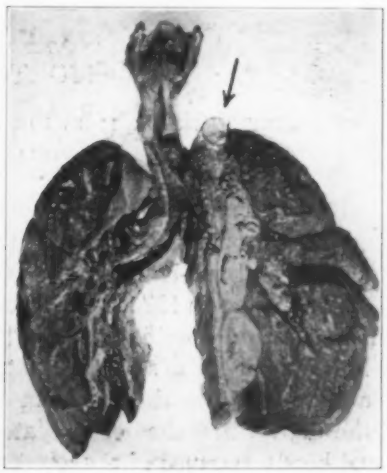

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 2. A lateral roentgenogram of the thoracic spine, which shows no evidence of a destructive lesion of the vertebral bodies.

Fig. 2-B: Postmortem specimen of lungs, showing tuberculous caseous tract.

Fig. 2-C: Microscopic section shows caseous mass in upper portion, marked thickening of the dura, and pressure on the spinal cord.

(Fig. 2-B). This sinus extended laterally around to the back, involved the spinous processes of the third, fourth, and fifth thoracic vertebrae, extended through the intervertebral foramina into the canal, and caused compression of the spinal cord at this level (Fig. 2-C). On the thoracic surface of the spinal cord was a large tuberculous caseous mass which had not invaded the cord, but which had caused a marked thickening of the dura and had thus compressed the cord.

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MORTON'S METATARSALGIA

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This report is based on the clinical and pathological findings recorded in twenty cases of Morton's metatarsalgia, treated at the Charlotte Memorial Hospital during the past three and one-half years.

As long ago as 1876, Morton of Philadelphia reported that certain cases of metatarsal pain fell into a specific group. This syndrome of plantar metatarsal pain has come to be known as Morton's toe. Morton's original explanation was that this condition was due to a disturbance in the fourth metatarsophalangeal articulation, or possibly to pinching of the digital branches of the lateral plantar nerve between the fourth and fifth metatarsal heads, because of the great mobility and play of the fifth metatarsal.

Betts described this syndrome in 1940 as one associated with a change in the fourth plantar digital nerve. He ascribed the condition to a stretching and irritation of this nerve, which differs anatomically from the other plantar digital nerves in that it has a double origin,—one branch from the medial plantar nerve and one branch from the lateral plantar nerve. After anastomosing, the nerve, as described by Baker and Kuhn, "continues distally between the flexor brevis muscle and the plantar aponeurosis just proximal to the heads of the metatarsals, where it penetrates the aponeurosis and passes beneath the transverse metatarsal ligament. Just distal to the ligament it turns upward into the web space between the third and fourth toes, where it divides into the medial and lateral branches which supply the adjacent sides of the third and fourth toes."

Betts theorized that, because this nerve was thicker and more fixed, it was thus prone to stretching and irritation during dorsiflexion of the foot.

McElvenny brought this syndrome, with its modern etiological conception, before the medical profession in 1943. He found that surgical treatment of this syndrome—that is, excision of the tumor between the third and fourth toes at the plantar level of the bases of the proximal phalanges—gave relief.

In 1944, Baker and Kuhn of Duke University reported eighteen dissections on cadavera and found the anatomical relationship previously reported by Betts. They also reported a series of fourteen operations on eleven patients (three of the patients had bilateral pain).

Authors of textbooks of anatomy describe the medial plantar nerve as terminating in four plantar digital nerves, the first supplying the medial side of the great toe, the second supplying the opposing faces of the big toe and the second toe, the third supplying the opposing faces between the second and third toes, and the fourth supplying the opposing faces of the third and fourth toes. The lateral plantar nerve ends in two terminal branches, the medial one supplying the interval between the fourth and fifth toes and the lateral one supplying the lateral portion of the little toe. Thus the dissections by Betts and by Baker and Kuhn show more clearly why the interspace between the third and fourth metatarsal heads, supplied by the fourth plantar digital nerve (which is composed of branches from both lateral and medial plantar nerves), is the site of the majority of these irritative lesions of the plantar digital nerves.

In reviewing the records of the twenty cases treated at Charlotte Memorial Hospital, we find that the patients usually have had the symptoms for some time, and have already tried various measures to relieve the pain, without success. The pain is described as being localized near the fourth metatarsal head, sometimes radiating up the leg. It is often so intense that the patient has to take off his shoe to rub or press the painful area. In

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addition, tingling and numbness of the third and fourth toes may be noted. Examination reveals a normal-appearing foot. There is localized tenderness on pressure in the region between the third and fourth metatarsal heads, sometimes more intense on the plantar surface and sometimes on the dorsal surface. Sensory changes may be present in the third and fourth toes. A nodule can occasionally be palpated deep in the third web space. Roentgenograms fail to show evidence of abnormality.

In this series of twenty cases, there were no complications. Two patients had delayed healing of the incision, but made uneventful recoveries. There have been no untoward consequences as a result of sectioning this nerve, and no painful neuromata; no trophic disturbances have developed.

There is little variation in the clinical symptoms presented, so that it is possible to predict with fair accuracy that a patient with typical symptoms will receive relief only from operation.

Because of the similarity of these cases, only one is summarized to illustrate this condition.

W. E. P. The patient was a white housewife, twenty-six years of age. Exquisite, lancinating pain had been present in the region of the third and fourth toes of the right foot for at least a year before the patient was seen. There was tingling of the third and fourth toes. No relief had been obtained from changes of shoes, or from the use of metatarsal pads, arch supports, or metatarsal bars.

Examination of the foot showed no alteration of normal contour. There was tenderness on firm pressure in the area between the third and fourth metatarsal heads, with slight radiation and numbness on the outer aspect of the third toe and the medial aspect of the fourth toe. A roentgenogram of the fore part of the foot was essentially negative.

An operation was performed on November 8, 1943. With the use of sodium pentothal anaesthesia and an Esmarch bandage, a small longitudinal incision was made on the dorsum of the foot, over the interspace between the third and fourth metatarsal heads. Upon separation and dissection of the fatty tissue, the fourth plantar digital nerve was found to have a nodular enlargement as it emerged from the plantar fascia. This was resected, with about half an inch of the nerve.

The postoperative course was quite satisfactory. The patient was dismissed from the Hospital on November 13, with a protective dressing. On November 18, when the sutures were removed, the wound had healed, and the patient was given a split shoe for walking. She was apparently completely relieved of her symptoms.

On February 2, 1947, the patient reported to the office with a complaint of low-back difficulty. Inquiry was made about the foot, and the patient could not remember at first which foot had been operated upon. She stated that she was completely free of symptoms, that she carried on normal housework, and had had two children in the interval since her operation.

PATHOLOGICAL FINDINGS

The gross examination of all the specimens revealed a marked fusiform thickening of the plantar nerve. No attempts were made to determine accurately the diameter, since it was obvious that a good deal of fat and connective tissue had been removed with the nerve. A definite line of cleavage between the tumorous swelling of the nerve and the surrounding tissue could not be detected.

Histological sections showed similar changes in all cases, consisting of massive thickening of the connective-tissue elements of the nerve. Extreme fibrosis and hyalinization of the perineurium were found consistently in all instances, but in most of them the process also extended into the endoneurium, thus separating nerve bundles as well as nerve fibers from each other (Figs. 1, 2, 3, and 4). Perineurium and epineurium blended imperceptibly into the adjacent connective tissue. Attempts to demonstrate changes in the nerve fibers by myelin-sheath stains did not yield conclusive evidence, although changes were noted which were suggestive of degeneration. Fat-laden macrophages were absent.

The increased amount of collagenous connective tissue was characterized by relative paucity of nuclei, and was not suggestive of new growth. There was no evidence of proliferation of Schwann's cells. Inflammatory infiltration was absent, but occasionally iron-

pigmented macrophages were found, indicating previous hemorrhage, possibly due to trauma.

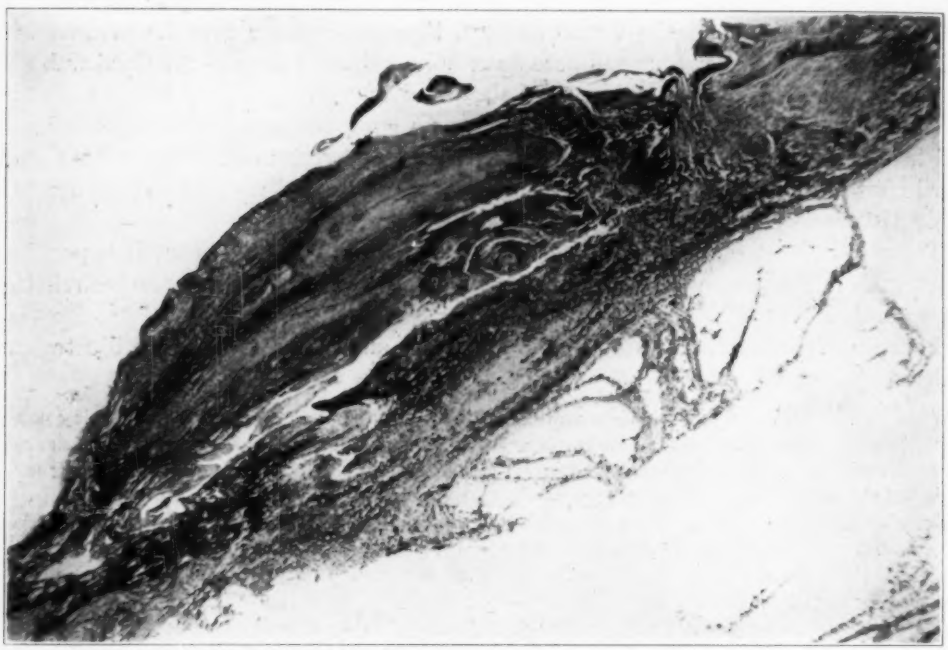

FIG. 1

Showing spindle-shaped enlargement of nerve (low-power magnification).

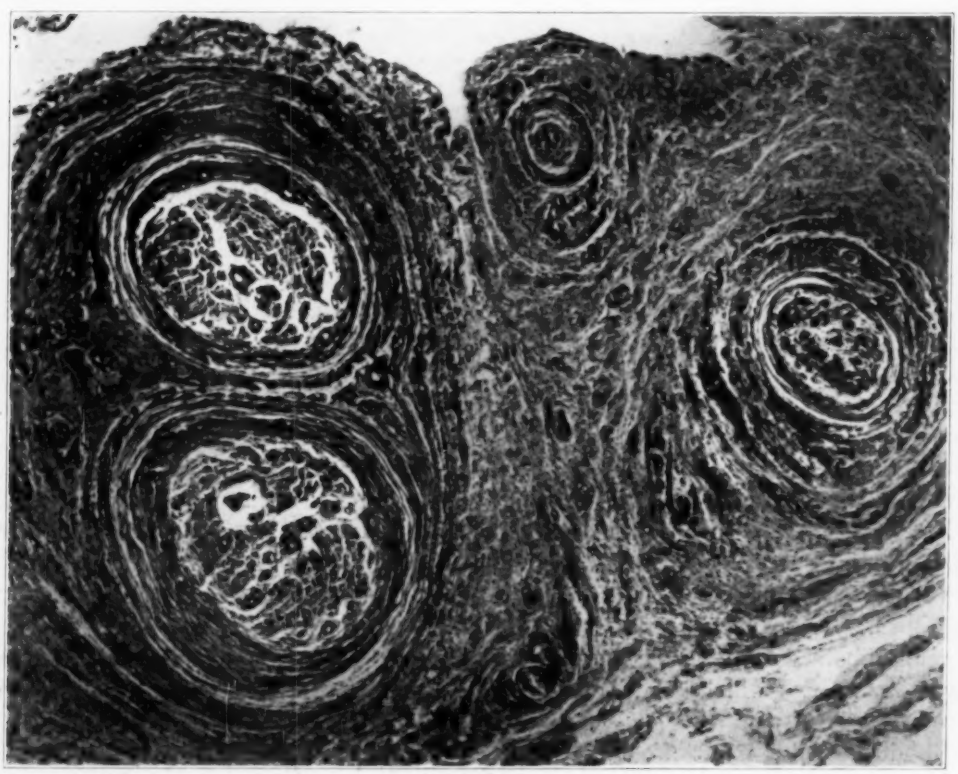

FIG. 2

Cross section through nerve, showing extreme thickening of perineurium (low power).

FIG. 4

Showing deposit of hyaline material in perineurium and the rather indistinct border of perineurium and nerve tissue (high-power magnification).

FIG. 3

Cross section, showing thickening of perineurium and some thickening of endoneurium (medium-power magnification).

CONCLUSIONS

The authors' findings agree essentially with those of Baker and Kuhn. We did not find changes which could be interpreted as evidence of active proliferation of either nerve tissue or connective tissue. The deposition of hyaline and collagenous material in itself accounts for the enlargement, in our opinion. We believe, therefore, that the process is essentially degenerative in nature, trauma being its most probable cause.

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THE pH OF THE SYNOVIAL FLUID IN THE ANAESTHETIZED DOG UNDER TREATMENT WITH METRAZOL OR INSULIN*†

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Exchanges of electrolytes between the synovial cavity, blood, and interstitial fluids depend upon changes of electrolyte concentration of these fluids, and also upon autonomic activation of the vascular system in surrounding tissues [2,3]. Muscle activity results in lowering the pH of synovial fluid by the formation of acid metabolites. In periods of rest following muscle activity, the pH returns approximately to the original resting level, the rate of recovery depending upon the state of the circulation as determined by autonomic regulation.

As part of a systematic study of the effects of autonomic and central controls over synovial fluid, the investigation described here was planned to determine the pH of synovial fluid *in vivo* after the administration of metrazol or insulin. The purpose is to define the effects of the resulting convulsions on the pH of the blood and synovial fluid in animals with intact nervous systems. The pH changes are related to systemic conditions in both the pre-convulsive and actively convulsive phases of the drug action. The comparison of blood and synovial-fluid pH indicates the nature of electrolyte exchanges between these fluids in the two phases.

* The expenses of this investigation were in part defrayed by the Arthritis Research Project of the University of Illinois.

† A preliminary report of this work was presented before the American Physiological Society, May 20, 1947; and an abstract was published in *Federation Proceedings*, **6:** 211, 1947.

TABLE I

METRAZOL CONVULSIONS IN DOG NO. 3 *

Time (*Minutes*)	pH in Left Knee Joint	pH in Left Femoral Vein
2		7.49
3		7.47
4		7.46
4½		7.46
5½		7.50
6		7.46
8	7.41	
10	7.34	
10½	7.34	
12		7.46
14		7.44
16	7.39	
16½		7.46
18	7.38	
19½		7.46
21	Injection of metrazol (6 cubic centimeters of 10 per cent. metrazol in sodium citrate)	
21½	7.40	
22½	7.40	
23	Convulsions	
26½	7.27	7.34
27½		7.30
29	7.20	
30		7.33
32	7.17	
34		7.30
35	7.11	
38	7.10	
40	7.14	
45		7.35

* This dog weighed 22 pounds; nembutal was used as anaesthetic.

EXPERIMENTS

The method of determining *in vivo* the pH of blood and synovial fluid in dogs has previously been described in detail [2,3]. Needle reference electrodes were inserted into an exposed femoral vein and into the knee-joint cavity on the same side. Capillary glass electrodes were immediately inserted into the needles, and readings of electromotive force were made over a period of ten or fifteen minutes until several consecutive readings agreed within two or three millivolts for any given pair of electrodes. Metrazol or insulin was then injected into the heart, and pH readings were made at frequent intervals in the femoral venous blood and in the synovial fluid on the corresponding side. These were continued through both the pre-convulsive and convulsive stages for each of the two drugs. All dogs were anaesthetized with nembutal.

Complete records for two different dogs, one treated with metrazol and one with insulin, are presented in Tables I and II. Results are illustrated graphically in Figure 1 for metrazol, and in Figure 2 for insulin.

RESULTS

1. *Metrazol*

The effects of metrazol were studied on six animals. The drug, in sodium citrate

solution, was injected in sufficient quantity to cause convulsions. In several instances two or three injections were required, the first one sometimes resulting only in muscle tremors or increased muscle rigidity. Results on six of the animals are presented in Figure 1, *1*. In every experiment, after the onset of convulsions, there was a sharp fall in pH in the synovial fluid and a much less pronounced fall in blood pH. In the pre-convulsive stages, after the injection of the drug, there appeared to be no significant changes in the pH of either fluid. However, immediately after the beginning of convulsions, marked changes

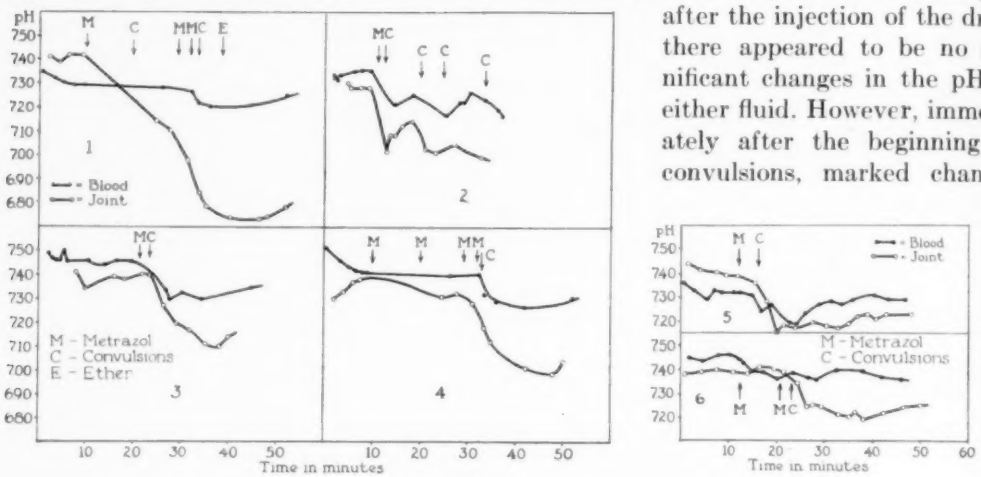

FIG. 1

Responses to metrazol. The maximum depression of the pH usually tended to appear later in the synovial fluid than in the blood; it was of greater magnitude and returned to the previous level more slowly.

in the pH occurred in the direction of increased acidity. In most of the cases, the blood pH varied within a range of about 0.15 after the injection of metrazol, while the synovial-fluid pH was observed to vary over two to four times that range. There was no marked parallelism between the two.

In Table III, the results for six animals are shown, expressed in a different manner. The resting pH is given for both blood and joint fluid, together with the pH at the maximal displacement and the time of the maximal displacement, measured from the first injection.

In most of the cases the maximal change of joint pH was about two or three times as large as the maximal change of blood pH, and it usually occurred at a later phase of the convulsions. The results

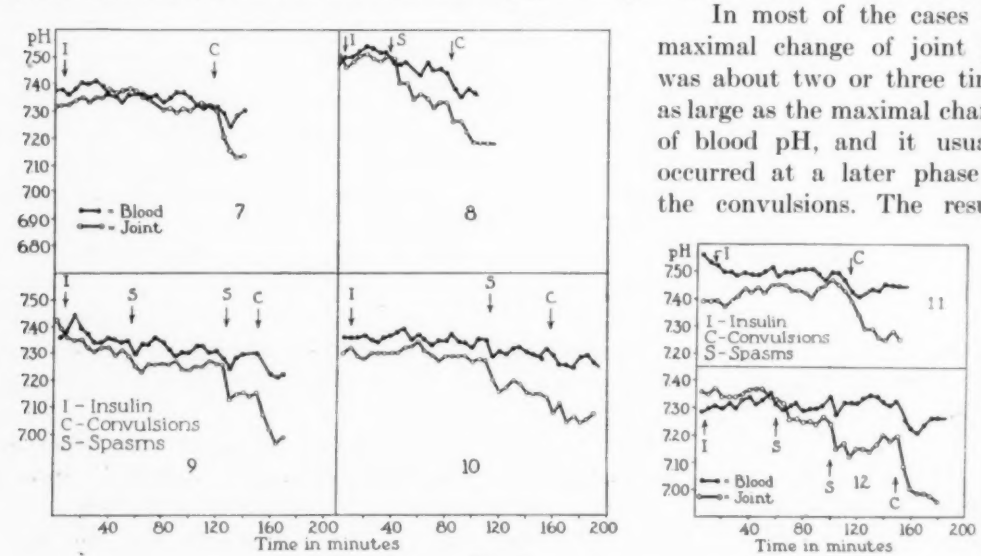

FIG. 2

The responses to insulin were of less magnitude in both fluid and blood, and tended to be parallel. Also, the pH was less regular in both sites. Insulin convulsions were less effective than those due to metrazol.

TABLE II

INSULIN CONVULSIONS IN DOG NO. 7 *

Time (*Minutes*)	pH in Right Knee Joint	pH in Right Femoral Vein
1	7.24	
2	7.29	
3		7.43
4		7.39
5	7.33	
6		7.37
8	7.34	
10	7.32	
12		7.39
13		7.38
14	7.32	
15	7.32	7.38
20	7.32	7.38
21½	Injection of insulin (200 units)	
25	7.32	7.36
30	7.34	7.38
35	7.35	7.41
40	7.33	7.40
45	7.35	7.41
50	7.35	7.39
55	7.38	7.36
60	7.36	7.35
65	7.38	7.33
70	7.38	7.36
75	7.37	7.36
80	7.35	7.36
85	7.34	7.35
90		7.36
95	7.30	7.33
100	7.31	7.35
105	7.29	7.37
110	7.31	7.37
115	7.30	7.35
120		7.32
125	7.33	7.31
130		7.32
130	Onset of convulsions	
135	7.30	7.31
140	7.20	7.29
145	7.15	7.24
150	7.12	7.28
155	7.12	7.30

* This dog weighed 25 pounds; nembutal anaesthesia was used.

plotted in Figure 1, *1* indicate that the joint pH progressively became more acid than the blood pH.

2. *Insulin*

The effects on blood and joint pH of convulsions induced by insulin were determined on six dogs, anaesthetized with nembutal. The results of these experiments, presented graphically in Figure 2, show the variations of pH over a period of time, including a comparatively long pre-convulsive period and a period of active spasms and convulsions. After administration of insulin, as also following injection of metrazol, muscle activity, manifested in spasms or convulsions, resulted in lowering of the pH of both blood and joint fluid. The variations of joint pH were generally greater than those of the venous blood.

TABLE III

DISPLACEMENT OF pH OF BLOOD AND OF JOINT FLUID AFTER INJECTION OF METRAZOL

Dog No.	Blood * pH		Joint pH		Time from Injection of Drug to Maximal Displacement	
	Resting	Displaced	Resting	Displaced	Blood (*Minutes*)	Joint (*Minutes*)
1	7.29	7.20	7.41	6.73	26	36
2	7.36	7.16	7.28	6.99	14	21
3	7.46	7.30	7.40	7.10	7	17
4	7.40	7.27	7.38	7.00	32	38
5	7.32	7.19	7.39	7.15	12	8
6	7.46	7.37	7.39	7.19	8	26

* Femoral vein.

There was little tendency for the joint pH to follow closely the variations of blood pH. It was observed that pH changes of both fluids were most pronounced whenever vigorous muscle movements occurred during spasms or convulsions.

As in the series of metrazol experiments, it was observed that the range of variability of synovial-fluid pH was greater than that of blood pH. During insulin convulsions, the blood pH rarely fell more than 0.2 below the resting level. The pH of synovial fluid during severe convulsions often deviated from the resting value by about 0.4 or 0.5 unit. On the whole, in insulin convulsions, there appears to be a more distinct parallelism between the curves of blood pH and joint pH than in the experiments with metrazol. With neither drug, however, can any highly correlated parallelism be observed. There was a tendency in each of the experiments with insulin for both pH curves to pass through a series of roughly corresponding maxima and minima, the sharpest minima occurring immediately after periods of muscle spasms or convulsions. The general trend, plotted over a period of two to three hours, however, showed a tendency for the joint pH to become considerably more acid than the blood pH. This tendency is similar to that observed in the metrazol series, where, however, the effects were more acute and appeared in a much shorter time.

DISCUSSION

In an earlier investigation it was found that, following femoral-nerve stimulation and muscle contraction, the pH of the synovial fluid and that of the femoral venous blood fell immediately; the blood pH recovered in a few minutes, while the pH of the joint fluid often remained acid for a much longer time. These effects are in contrast to those observed after the intravenous injection of dilute acids, when the blood pH rapidly decreased, passing through a minimum and approaching the original level within a few minutes. The pH of the synovial fluid, however, decreased much more slowly and by a smaller amount, reaching a minimum considerably later and recovering much more slowly than the blood pH. It was pointed out that acid metabolites, produced in the tissues, were transferred to synovial fluid more rapidly than acids injected into the circulation. This fact points to a close relationship between synovial fluid and tissue fluid. The capillary circulation also must be considered to exchange water and electrolytes with both synovial fluid and tissue fluid. These exchanges would depend not only on differences in concentrations of various diffusible ions and of the colloids in the fluids, but also on membrane permeabilities and on hydrostatic pressure gradients. A considerable number of physiological, as well as physicochemical, factors must thus be involved in the situation. These considerations agree well with the conclusions reached by Bauer, Ropes, and Waine.

The results described in the series of experiments with metrazol and insulin are consistent with this conception of the problem. Acid metabolites produced during muscle

activity appear to have been transferred rapidly to the joint cavity without the mediation of the capillary circulation. The joint pH thus fell rapidly after severe muscle spasms or convulsions. This effect is in contrast with the previously observed delayed response of joint pH to dilute acids injected into the circulation. The relatively large pH changes in the synovial fluid, as compared with those of the femoral vein, also indicate that the synovial-fluid pH is determined by electrolytes produced in the active tissues, which are almost immediately transferred to the joint cavity. Recovery of the pH after displacement depends upon circulatory removal of the accumulated metabolites during the resting phase.

In the observations that have been reported, the rate of recovery in the resting phase is invariably slower than the rate of pH displacement in the periods of muscle activity. These observations thus agree with earlier ones which indicated that the joint pH is more rapidly lowered by acids produced in the tissues than by acids injected into the circulation. Diffusion of hydrogen ions between the joint cavity and the capillaries appears to be a slower process than diffusion between the tissue fluids and the joint cavity.

SUMMARY

This paper reports the results of alterations in the pH of synovial fluid and of blood of dogs anaesthetized with nembutal, in response to agents producing extreme muscle activity.

The intravenous administration of metrazol, in doses producing convulsions, resulted in a more pronounced decrease in the pH of synovial fluid than in that of blood. This difference was progressively developed to a maximum stage somewhat later than in blood.

The injection of insulin produced similar, but less pronounced, results, although the graphs were less smooth and regular and there was better correlation between the alterations of pH in the two fluids.

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MECHANICAL RETARDATION OF BONE GROWTH

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In a previous paper[1], a method was presented for the retardation of bone growth by means of a loop of wire, encircling the epiphyseal cartilaginous plate. The loop of wire prevented the epiphysis from being advanced forward, as occurs normally after the laying down of new bone in the metaphyseal-epiphyseal region. It was found that the restraining power of the wire loop did not permanently destroy the proliferative properties of the columns of cartilage cells of the epiphyseal plate, and bone growth was resumed after the release of this hindering force. It was also shown that a loop of wire around one side of an epiphyseal cartilaginous plate restricted growth on the side of its insertion, with a resulting asymmetrical growth at that articular end of the bone.

Although the cartilaginous plate was restrained only temporarily, the question arose as to whether or not there was any loss in relative activity as compared with the normal rate of growth. The question was also asked as to whether or not premature closure of the plate might take place, due to the temporary mechanical brake.

In an endeavor to solve some of the problems of growth, a series of experiments were performed on growing dogs. In this series, staples were used instead of the wire loop. In one set of experiments, the staples were inserted on both sides of the plates and were allowed to remain in position until the termination of the experiment. In another series, the staples were removed after the lapse of a certain length of time, and growth studies were continued until the end of the experiment. In other experiments, staples were inserted on only one side of the cartilaginous plate.

Some interesting findings were obtained from these experiments, which may be of practical significance. These findings will be discussed after the results of the operations have been reported.

I. STAPLES ON BOTH SIDES OF EPIPHYSEAL CARTILAGINOUS PLATE

Experiment 1, Dog 4

Method: Staples were inserted laterally and medially across the distal epiphyseal plate of the right radius.

Result: Forty-six days later, the growth of the normal left radius was 2.2 centimeters. The growth of the bone on the side operated upon was 1.4 centimeters. The loss of growth was 0.8 centimeter.

Experiment 2, Dog 5

Method: A staple was driven across the distal epiphyseal plate of the left femur, both laterally and medially.

Result: One hundred and forty-one days later, the growth of the normal femur was 1.8 centimeters. The growth of the femur which had been operated upon was 0.8 centimeter. The loss of growth was 1.0 centimeter.

Experiment 3, Dog 6

Method: A staple was placed on both the lateral and medial aspects of the proximal epiphyseal plate of the left tibia.

Result: Forty-five days later, there was 0.5 centimeter of difference between the length of the normal tibia and of that which had been operated upon. The staples had not been inserted very firmly.

FIG. 1

FIG. 2

Fig. 1: Experiment 4, Dog 7. Long staples were inserted on both the lateral and medial aspects of the epiphyseal plate. There was growth of 1.4 centimeters on the normal side and 0.5 centimeter on the side of the inserted staples.

Fig. 2: Experiment 5, Dog 1. Staples were inserted over the lateral and medial aspects of the distal epiphyseal cartilaginous plate. Growth on the normal side at the end of seventy-seven days was 3.2 centimeters; growth on the side which had been operated upon was 1.6 centimeters. There was no deformity at the articular surface. The staples were removed at the end of this period.

Experiment 4, Dog 7

Method: Staples were inserted both medially and laterally across the distal epiphyseal plate of the left femur.

Result: Two hundred and five days later, growth of the right femur was 1.4 centimeters. The growth of the femur which had been stapled was 0.5 centimeter. There was loss of growth of 0.9 centimeter (Fig. 1).

Summary of the Results with Bilateral Staples

There was an arrest of length growth in every case in which staples had been inserted on both sides of the epiphyseal cartilaginous plate. The amount of growth from the proximal epiphyseal cartilaginous plate was greater than one would anticipate from the normal ratio of 3 to 1. There is a possibility of compensatory growth from the non-arrested epiphyseal plate.

II. STAPLES INSERTED ON BOTH SIDES OF THE EPIPHYSEAL PLATE AND REMOVED LATER

Experiment 5, Dog 1

Method: Staples were inserted both medially and laterally across the distal epiphyseal plate of the right radius. They were removed at the end of seventy-seven days; observations were continued for 185 days (Fig. 2).

Result:

	At 77 Days	*From Removal of Staples to 185th Day*
Growth of normal radius	3.2 centimeters	1.1 centimeters
Growth on side which had been operated upon	1.6 centimeters	0.8 centimeter

After removal of the staples, the relative growth was 1.4 to 1; while before removal it had been 2 to 1. This was a considerable increase in growth rate, but it was not so active as the normal after removal of the restraining force.

Experiment 6, Dog 2

Method: Staples were inserted medially and laterally across the distal epiphyseal plate of the right radius. At the end of eighty-four days the staples were removed; the experiment was continued for 143 days.

Result:

	At 84 Days	*From Removal of Staples to 143rd Day*
Growth of normal radius	3.4 centimeters	0.7 centimeter
Growth on side which had been operated upon	1.9 centimeters	0.4 centimeter

There were signs of earlier ossification on the side which had been operated upon, suggesting an injury to the plate. This might account for the failure of increase in rate after removal of the restraining force.

Experiment 7, Dog 9

Method: Two staples were inserted on both the medial and lateral aspects of the distal epiphyseal cartilaginous plate of the right femur. They were removed at the end of eighty days. The experiment was continued until the one hundred and eighty-seventh day.

Result:

	At 80 Days	*From Removal of Staples to 187th Day*
Growth of normal bone	2.6 centimeters	0.9 centimeter
Growth of bone on side operated upon	1.4 centimeters	0.4 centimeter

There was a little acceleration in the rate of growth after removal of the staples. Considerable difficulty was experienced in removing the staples, with some injury to the bone in the region of the plate.

Experiment 8, Dog 8

Method: Two staples were inserted across both the medial and lateral aspects of the distal epiphyseal plate of the right femur. They were removed after ninety days, and the experiment was continued for 348 days.

Result:

	At 90 Days	*From Removal of Staples to 348th Day*
Growth of normal bone	3.5 centimeters	1.5 centimeters
Growth of bone on side operated upon	2.0 centimeters	1.0 centimeter

The rate of growth of 1.7 to 1 was increased to 1.5 to 1. The animal was near the end of the growth period at the time the staples were removed.

Summary of Results with Staples on Both Sides of the Plate, Subsequently Removed

There was an arrest of growth at the epiphyseal plate which had been operated upon, up to the time of removal of the staples. The rate of growth increased after removal of the staples, but it was not so rapid as the normal rate of growth. There is the possibility of injuring the plate when removing the staples, and of disturbance in circulation, which may hinder the function of the epiphyseal plate.

III. STAPLES PLACED ON ONLY ONE SIDE OF EPIPHYSEAL CARTILAGINOUS PLATE

Experiment 9, Dog 1

Method: Two staples were placed across the lateral aspect of the epiphyseal plate at the distal end of the left femur.

Result: Two hundred and fifty-nine days later there was a difference of 0.6 centimeter in length of the two bones; the loss was 1.3 centimeters during the first 100 days. The hip

became dislocated during the experimental period, which may explain the difference in rate of growth.

Experiment 10, Dog 2

Method: Two staples were placed across the lateral epiphyseal plate at the distal end of the left femur.

Result: Three hundred and six days later the growth of the normal medial and lateral condyles was 2.3 centimeters. There was only 2.0 centimeters of growth of the medial condyle and 1.5 centimeters of growth of the lateral condyle of the bone which had been operated upon. This represents a growth loss of 0.3 centimeter of the medial condyle and 0.8 centimeter of the lateral condyle of the femur which had been operated upon.

Experiment 11, Dog 3

Method: Two staples were placed across the lateral aspect of the epiphyseal plate at the distal end of the right radius. One staple was removed after eighty-four days; the experiment was continued for 202 days.

Result:

	At 84 Days	*At 202 Days*
Normal bone growth	4.0 centimeters	5.0 centimeters
Growth of bone operated upon		
Medial	2.9 centimeters	3.7 centimeters
Lateral	2.5 centimeters	3.1 centimeters

FIG. 3

FIG. 4

Fig. 3: Experiment 11, Dog 3. Staples were placed on the lateral aspect of the epiphyseal plate of the distal end of the right radius.

Growth of the normal bone at the end of eighty-four days was 4.0 centimeters. Growth on the medial side of the bone which had been operated upon was 2.9 centimeters; on the lateral aspect it was 2.5 centimeters. The staples had become displaced during the interval, allowing more growth from the distal end than would have occurred if they had remained in position. Notice the angulation of the articular surface and the difference in length between the normal bone and that which was operated upon.

Fig. 4: Experiment 12, Dog 3. A long staple was inserted over the lateral epiphyseal plate of the left femur. Roentgenograms of the dissected specimen show the loss of growth, and also the deformity of the articular surface of the lower end of the femur. (This roentgenogram has been reversed.)

The staples became displaced during the growth of the bone, but the retention was sufficient to hinder growth on both sides. As the staples became displaced, there was 1.0 centimeter of growth from the distal epiphysis (Fig. 3).

Experiment 12, Dog 3

Method: A long staple was driven across the epiphyseal plate on the lateral aspect of the distal end of the left femur. The duration of the experiment was 102 days.

Result:

	At 102 Days
Normal bone growth	2.4 centimeters
Growth of bone operated upon	
Medial	1.0 centimeter
Lateral	0.5 centimeter

The articular end of the bone which had been operated upon was widened. There was a loss of growth of the medial condyle of 1.4 centimeters, and a loss of growth of the lateral condyle of 1.9 centimeters (Fig. 4).

Experiment 13, Dog 5

Method: Three staples were placed across the lateral epiphyseal plate at the distal end of the right radius. Two staples were removed on the eighty-first day; the observation continued until the one hundred and eighty-eighth day.

Result:

	At 81 Days	*At 188 Days*
Normal bone growth	3.0 centimeters	3.8 centimeters
Growth of bone operated upon		
Medial growth	2.0 centimeters	2.3 centimeters
Loss	1.0 centimeter	1.5 centimeters
Lateral growth	1.8 centimeters	1.8 centimeters
Loss	1.2 centimeters	2.0 centimeters

The epiphyseal plate appeared to be undergoing premature closure.

Experiment 14, Dog 6

Method: Two staples were inserted on the medial side of the epiphyseal plate at the distal end of the right radius. Two sinuses developed, but they healed promptly.

Result:

	At 118 Days
Normal bone growth	2.5 centimeters
Growth of bone operated upon	
Lateral growth	1.9 centimeters
Loss	0.6 centimeter
Medial growth	1.4 centimeters
Loss	1.1 centimeters

Summary of Results with Unilateral Staples

Staples inserted on one side will prevent growth on that side. There will also be a retardation of growth on the opposite side, but to a lesser degree. There will be a diminution of the total length of the bone by staples inserted on one side.

COMMENTS

One of the important findings in this set of experiments is concerned with the insertion of staples on one side of the epiphyseal cartilaginous plate. There was a complete hindrance of growth on the side of their insertion. A marked loss in length growth was found on the opposite side as well, causing a decrease in the total growth of the entire bone as compared with the normal. In reviewing the original experiment with the use of a wire loop on one side of the plate, it was found that there was also a loss in total length; but the significance

of this result was not appreciated at that time. One should consider carefully the application of this principle, which was recommended at that time as a means of compensating for deformity due to unilateral overgrowth of a bone. In retrospect, it is obvious why there is a loss of length growth on the opposite side. The growth in length is caused by the laying down of new bone at the juncture of the metaphysis and epiphysis. This new bone pushes the epiphysis away as a block or cylinder of bone. The wire loop or staple, passing into the epiphysis on one side, will exert a restraining force on the whole epiphysis; this will be complete at the side of insertion, but less effective on the opposite side.

The arrest of growth by a unilateral wire or staple, when utilized clinically, may correct a growth deformity, but at the same time there is the possibility of arresting total growth in length. One should be careful, also, in the selection of the type of lesion for unilateral growth arrest. If the deformity is due to destruction of the plate on one side from injury or disease, it is easy to see why a unilateral staple will not correct the deformity, because the injured plate has lost its power to proliferate and to push the epiphysis ahead on that side. In fact, a restriction is present on both sides, and a staple would merely prevent further deformity and length growth. Repeated osteotomies to correct the deformity would be advisable.

On the other hand, deformity due to some factor apart from the plate or to some disease which has not completely destroyed the growth power may be corrected by a unilateral growth arrest. The loss of total growth will have to be kept in mind. It is possible in humans, where there is a long growth period, that a compensatory growth increase may take place.

Clinical application and long-time growth observations would be important to decide this point, or experiments on an animal with a longer active growth period than that of the dog, which is not more than nine months.

The question as to whether or not growth is normal after the removal of the wire loop or bilateral staple is difficult to answer. In the first place, additional disturbances to the circulation undoubtedly occur in the removal of the wire or staple, which will have some inhibiting effect on growth. Then there is the possibility of mechanical injury in removing the wire or staple, which becomes more or less imbedded with the lapse of time. If trauma has been sufficient, an osseous bridge may form after the operation, restricting growth. In some of the experiments an increase in the rate of growth undoubtedly occurred after removal of the staple, but it did not reach that of the normal. However, the active growth period of the dog is less than nine months, so that it is difficult to say what would happen in the human being, where the period of growth continues for many years. Experiments on animals with a longer period of growth should be performed to obtain further information on this particular phase of the subject.

In some of the experiments, there was evidence of premature closure of the epiphyseal plate. This usually took place near the time of normal cessation of growth. The findings were not uniform, and further studies are necessary.

In some cases in which staples were inserted on both sides of the epiphyseal plate, there was broadening of the articular end of the bone. There was also a tendency for some of the plates to be rotated and to assume a different location from their original site. It is possible that an irregular or asymmetrical growth disturbance may play a factor in these observations.

It is important to make careful follow-up observations and to take repeated roentgenograms in cases of growth arrest by mechanical means. In humans, this is borne out by the clinical findings in one patient, where a wire loop was inserted around the epiphyseal plate to arrest growth. During a period in which this patient was not followed closely, the wire broke on the lateral aspect, and an overgrowth took place on that side, causing genu varum. This had to be corrected subsequently by an osteotomy, which could have been avoided by repeated roentgenograms during the growth span.

CONCLUSIONS

Wire or staples, applied unilaterally across the epiphyseal cartilaginous plate, will arrest length growth on the side of insertion. There will also be restriction of growth on the opposite side to a lesser degree, but sufficient to cause a loss in length growth of the bone.

It is inadvisable to try to compensate for a growth deformity, due to a destructive injury to the plate on one side, by the insertion of a staple or wire on the opposite side of the plate.

If the deformity was caused by factors outside of the plate, it may be corrected by unilateral wires or staples, but loss in length of the bone may occur.

It is difficult to determine definitely whether or not growth is as active after temporary retardation by a wire or staples. It was not so active as on the normal side, but it is possible that injury to the circulation and trauma to the plate disturbed the growth. There was evidence of a premature closure of the plate in some of the experiments.

1. Haas, S. L.: Retardation of Bone Growth by a Wire Loop. J. Bone and Joint Surg., **27**: 25–33, Jan. 1945.

LATERAL VIEW OF THE PELVIS IN EXAMINATION FOR HIP DISLOCATION

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In those institutions where a number of persons are seen who have been injured in industrial, automobile, and farm-machinery accidents, an appreciable number of those hurt are examined roentgenographically for dislocation of the hip. The examination may reveal a simple dislocation of the head of the femur, but the usual finding is a dislocation of this type, combined with a fracture of the rim of the acetabulum.

The common procedure in such cases is to take stereoscopic films of the pelvis and both hips. Due to the fact that such an examination does not always give complete information, whenever possible, we have resorted to an additional roentgenogram, consisting of a direct lateral view of the entire pelvis. The need for additional information, in these cases, was brought to our attention by examination of those patients brought in with a dislocated hip or a fractured pelvis, complicated by pregnancy. The first such patient was not examined by lateral roentgenograms until after the fractures in the pelvis showed some evidence of healing. Measurements had been requested to determine whether or not the pelvic deformity would interfere with a normal delivery. On the lateral roentgenogram of the pelvis, taken for the purpose of measurement, the degree of posterior displacement of the head of the femur was demonstrated more accurately than could be determined from the stereoscopic films.

The technique employed and the position of the patient for such a roentgenogram are the same as used for the lateral view in pelvic-measurement examinations, fractures of the sacrum, and lesions of the lower lumbar spine and lumbosacral disc. Routine roent-

FIG. 2

FIG. 1

Fig. 1: Anteroposterior roentgenogram of the pelvis and both hips, showing an acetabular fracture and, in stereoscopic films, a dislocation posteriorly of the head of the femur.

Fig. 2: Lateral view of the same pelvis as seen in Fig. 1, showing the proper position of the patient. The posterior displacement of the head of the femur in relation to the acetabulum is also shown. This degree of displacement cannot be evaluated in the conventional anteroposterior stereoscopic films.

genograms of the pelvis and both hips are made first; and, if they show extensive fractures of the pelvis, then the lateral roentgenogram is omitted for obvious reasons. If the roentgenograms reveal only a dislocation of the femoral head, or a dislocation with an acetabular fracture, the patient is placed in the proper position on the Bucky table for a lateral roentgenogram of the pelvis. Sometimes it is more comfortable for the patient to lie with the injured hip on the table top instead of away from it. The additional roentgenogram not only shows the amount of displacement of the head of the femur, but also shows the position of any small bone fragments, if present, either inside or outside of the joint capsule. Such a roentgenogram is also of value in the check-up examination following manipulation for reduction in a simple dislocation without fracture.

Examinations with a portable machine, while the patient is in bed and in an extension apparatus, have not been satisfactory, either with or without a stationary grid.

SPIKE OSTEOTOMY FOR THE CORRECTION OF VARUS AND ROTARY DEFORMITIES OF THE HIP *

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From the Mount Sinai Hospital, New York City

The present description concerns a simple method of subtrochanteric osteotomy that provides firm postoperative stability in the correction of varus and rotary deformities of the hip. Transverse or oblique osteotomy planes, as generally utilized, are often unstable. Even when the original operation is planned and executed with complete accuracy, it is common for the fragments to slip, so that the final angular correction is less than that planned and the extremity is accordingly shortened.

Of course, compromised results of this sort can be averted by a number of expedients, but each presents certain disadvantages. Internal fixation by instruments of the Blount type make it impossible for the surgeon to adjust the osteotomy angle during the early postoperative period. The operation is prolonged and moderately difficult, and healing is often slow. Pins incorporated in plaster, as used by Schanz, Roger Anderson, and Irwin, have proved risky for routine use, because of the ease with which infection travels along the elements protruding from the skin. The plan of delaying angulation until after some callus has formed adds a routine and unnecessary operative procedure. The curved and the inverted V osteotomies preclude slipping only at a right angle to the plane in which the V or curve is constructed. When the plane of the V is anteroposterior, to prevent medial slipping, an extensive anterior approach is required.

The spike operation offers a simple method of avoiding most of these disadvantages. It is so simple that the procedure must have been utilized before, although no record of its performance has been found in the relevant literature. The objective of the operation is the creation of a spike on the distal fragment for insertion into the trabecular bone of the femoral neck (Fig. 1).

* Read before the Orthopaedic Section, New York Academy of Medicine, May 16, 1947.

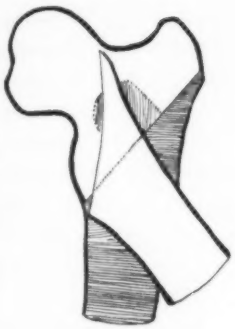

FIG. 1

Fig. 1: Diagram showing the objective of the operation.

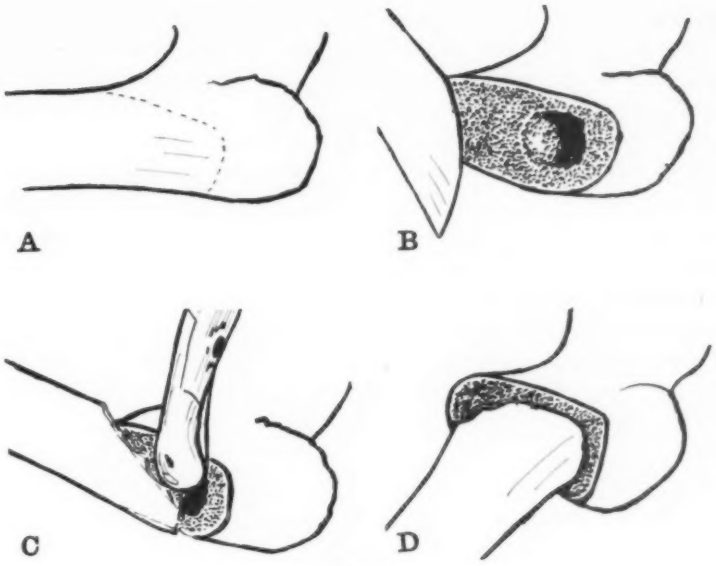

FIG. 2

Fig. 2: The operation.
A: The osteotomy plane.
B: The curetted pocket.
C: Trimming the spike.
D: Abduction and insertion of the spike.

Operative Procedure

Spike osteotomy is accomplished as follows: A lateral approach is employed, with circumferential subperiosteal exposure of the femur for two or three inches below the vastus ridge. The osteotomy plane commences just at the ridge, terminating medially just below the lesser trochanter (Fig. 2,*A*). Some care is necessary to avoid splitting the anterior cortex, and it has been found best to osteotomize this cortex first from its anterior aspect, this line of section being followed later from the side with the broad osteotome.

FIG. 3

D. K., aged five (No. 553131). Congenital coxa vara, left. A single plaster spica was worn for three months after operation, followed by prompt resumption of weight-bearing.

Distraction of the fragments is accomplished by adduction of the leg and by the use of bone hooks. In this position it is an easy matter to shape the distal fragment with the rongeur, and to create a pocket for the insertion of the spike into the trabecular bone of the proximal fragment (Fig. 2,*B*). This pocket may be curetted to follow any desired plane; a depth of one-half to three-quarters of an inch is ample (Fig. 2,*C*). Fitting the spike into the pocket presents no difficulty, but may require approximately one-quarter of an inch of shortening of the spike. Abduction locks the fragments firmly together in the rotary relationship that the surgeon desires, and the almost rectangular spike maintains it there (Fig. 2,*D*). The degree of abduction determines the corrective angle.

Postoperative immobilization is possible by a single or double spica, but, since abduction locks the position firmly, a leg-to-leg plaster only is required. This furnishes all the immobilization necessary for stability, and allows the patient greater postoperative freedom. For greater comfort it has been our practice to apply a single spica after the operation, changing it a week or two later for a leg-to-leg type of plaster.

Advantages

With the spike method, stability is attained at no sacrifice of leg length and even, in some cases, with gain. This stability is attained in a single-stage procedure without the use of foreign fixative material, and it is firm enough so that the single or double spica can be dispensed with. Abduction only is required, and this can be accomplished by a leg-to-leg plaster, from toes to mid-thigh. The operation preserves the ability to adjust the osteotomy angle during the early postoperative period. The broad osteotomy surface provided by the operation expedites bone healing, and blocks the characteristic tendency of osteotomies to "buckle" after the plaster has been removed. Because immobilization of the hip in plaster is unnecessary, the joint moves freely as soon as the leg plasters have been removed, and convalescence is speedy.

Indications

Spike osteotomy has been utilized only for angular and rotary corrections,—not for the therapy of ununited hip fractures. For obvious reasons the procedure cannot be satisfactorily executed when very small corrections are desired, nor can it be used when the hip is ankylosed, except in the presence of severe adduction deformity.

SKELETAL HEMANGIO-ENDOTHELIOMA

A Case Report

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Skeletal hemangio-endothelioma is a rare condition and one which is not easily recognized early. In order to help establish early diagnosis, and to evaluate the therapeutic measures usually employed, a report is presented of a patient who is still living nine years after the diagnosis of hemangio-endothelioma was confirmed. The case demonstrates some of the complications encountered, as well as indicating the possible prognosis. Since this patient had a single lesion in each hip, the question arose as to whether there were two primary lesions, or whether one was a metastasis. There are cases on record in which metastases have been reported. However, the history and course of the case herein presented led to the opinion that there were two primary lesions.

A white woman, forty years old, came to us, complaining of severe pain and swelling in the right hip. One year before, she had suffered a pathological fracture of the neck of the right femur. Roentgenograms made at another hospital had revealed, in addition to the fracture, a cystic lesion on the neck of the femur. She had been told at that time that she had but a few weeks to live. She lived, however, one year without much change in her symptoms, and it was then that she consulted the senior author. Physical examination showed the right leg to be one inch shorter than the left. The muscles of the right thigh were somewhat atrophic, and there was some swelling in the region of the greater trochanter. The red-cell and the white-cell counts were normal. The sedimentation rate was twenty-three millimeters per hour. Urinalysis revealed nothing unusual. There was no Bence-Jones protein. A roentgenogram (Fig. 1) confirmed the pathological fracture, with non-osseous union. The cystic lesion was also evident, but showed little change from its appearance in the roentgenograms which had been made one year before.

Since there was so little change in the lesion after a year, it was felt that it might not be malignant. The patient was admitted to Passavant Hospital for diagnosis. In case the lesion proved to be benign, immediate excision was to be performed. Roentgenographic studies of the chest and other long bones were made. There was nothing unusual in the chest, but the neck of the left femur showed a cystic lesion very similar to the one in the right hip. The presence of two lesions pointed toward malignancy, and it was believed that perhaps both were metastatic lesions from a primary site that had not yet been recognized. A thorough search for a primary lesion was made, but none was found. A subsequent roentgenogram (Fig. 2) showed an increase in the size of the lesions, and deep x-ray treatment was then advised. The maximum amount of therapy was given, but the lesions continued to grow. Radium needles were then inserted deep into the tumor tissue, but this treatment also failed to halt the disease. Roentgenograms (Figs. 3 and 4), made during this period, showed how the disease had progressed. All of the bones of the pelvis had become involved. Trabeculation and invasion of the surrounding soft parts had become prominent features in the roentgenograms.

FIG. 1

Roentgenogram made February 10, 1938, shows the cystic lesion and also the non-osseous union of the pathological fracture of the neck of the right femur.

The roentgenologist suggested that the lesion resembled that of echinococcus disease. In order to rule out any type of cyst or abscess, aspiration with a spinal-puncture needle was carried out. Serum was all that was obtainable. It was felt that a large trocar with a sharp edge could be used to obtain material for examination. After the trocar had penetrated the tissue, the plunger was withdrawn, and suction was applied. In this way a small amount of tissue was obtained. Laboratory analysis showed that the tumor was made up of small, irregu-

larly shaped cells, but no mitosis was evident. There was not enough tissue to establish definitely the type of tumor; therefore, it was decided to perform a biopsy. An incision was made above the greater trochanter of

FIG. 2

Roentgenogram made July 23, 1938, shows an increase in the size of the lesion of the right femur and the beginning of the cystic formation in the neck of the left femur.

FIG. 3

Roentgenogram made November 26, 1938, shows greater destruction of both femora and invasion of the surrounding soft parts. Also note the trabeculation.

the left femur. The tumor was found to be beneath the muscle. The muscle was divided; and, as soon as the tumor was encountered, there was profuse bleeding. The blood gushed forth so that it was necessary to con-

FIG. 4

Roentgenogram made April 18, 1939, shows the rapid progress of the destructive process. Invasion of the bony pelvis has taken place.

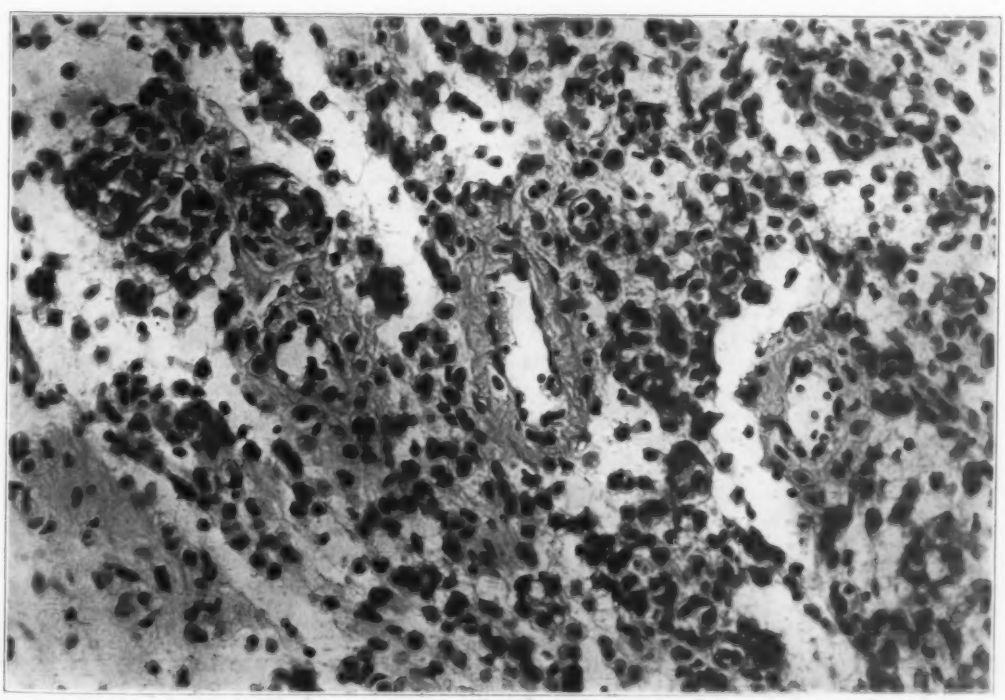

FIG. 5

Photomicrograph of section of tissue taken from the tumor shows the proliferating endothelial cells lining the blood vessels. In many areas the tumor cells have become arranged in whorls with a suggestion of a lumen in their midst.

FIG. 6

Roentgenogram made February 20, 1945, shows how the lesion has invaded almost the entire bony pelvis. (Shaft of the right femur not shown.)

trol the hemorrhage by blocking the opening through the muscle with a gloved hand. Palpation of the tumor revealed it to be made up of finger-like masses which invaded the bone. The tissue was soft and friable, and had the consistency of an oyster. Portions of these masses were removed with fingers and scissors. The muscle was packed immediately and firmly with a large gauze sponge. Then the muscle was sutured, as the pack was gradually removed.

The tissues were fixed, mounted, and stained with hematoxylin and eosin. Microscopically the sections (Fig. 5) showed a predominance of mature and immature endothelial cells, springing from the endothelial lining of the blood vessels. There were no mitotic cells. The tumor cells, in many areas, were arranged in whorls—cells piled one upon the other—with a suggestion of a lumen in their midst. The sections were similar to those studied by Kolodny. (Although the alveolar arrangement of the cells in Kolodny's cases was much more prominent than in this one, the other aspects were quite similar,—the tendency toward vasoformation, the presence of large cells containing vacuolated or scanty cytoplasm, and the proliferation of the endothelial cells lining the blood vessels.)

The patient recovered from the surgery, and is living today. The tumor has increased in size (Fig. 6), and it has invaded the entire pelvis. In spite of the enormity of the tumor and the pathological fracture, the patient is able to be up in a wheel chair occasionally. The pain has been controlled by various anodynes. Recently the patient has been receiving frequent doses of dilaudid hypodermically. She has survived pneumonia during which her temperature rose to 105 degrees. The fact that this patient has lived nine years without any further lesions seems to indicate that the two lesions are not metastatic. Furthermore, considering the period of time, the size of the tumor, and the amount of involvement, it is remarkable that the patient has lived so long.

DISCUSSION

To make an early diagnosis one must first suspect the existence of a hemangio-endothelioma. Any skeletal lesion which appears by roentgenogram to be (1) cystic, (2) trabeculated, and (3) invading the surrounding soft parts, merits the consideration of skeletal hemangio-endothelioma in the differential diagnosis. In all the cases in the literature which were examined roentgenographically, these three features were the outstanding characteristics of the lesions. This is also true of the case here reported.

The definitive diagnosis, however, rests upon the microscopic examination of a biopsy specimen. A biopsy should be performed on a lesion displaying any of the above features in order to differentiate it from (1) a benign cyst of the bone, (2) metastatic carcinoma, (3) giant-cell tumor, (4) osteosarcoma, (5) chondrosarcoma, (6) echinococcus disease of the bone, and (7) hemangioma. A microscopic examination of a sample of the lesion, which shows a predominance of mature and immature endothelial cells springing from the lining of the blood vessels, is, according to Kolodny, the only confirmation of the diagnosis.

Surgical intervention is the only procedure that at present offers any benefit. Of the twenty-three cases found in the literature, nine were treated surgically. Pritchard's patient was well three months later. In the case reported by Lutz and Pusch, the patient was well six months following surgery, at which time she died of coronary thrombosis. Petit-Dutaillis, Bertrand, and Messimy did not mention the longevity of their patient. They reported, however, that she became well, following excision of a hemangio-endothelioma from the occipital bone. Fienberg and Baehr did not report their postoperative results. Thomas reported a patient who was alive ten years after surgery. This is the longest period of survival following surgery among the reported cases. In another case, however, Thomas said nothing about the post-surgical course. One of the patients reported by Kolodny died four years after an amputation. Although no autopsy was performed, it was thought that death resulted from metastases. Jack and Faunce reported a case of a patient who died nine days postoperatively. The lesion had already metastasized to the brain. Stout reported a case in which metastases had developed three months following curettage of the lesion.

With regard to deep x-ray therapy, the literature and our experience with the case reported in this paper show that this type of therapy does not resolve the lesion. Pritchard, Lutz and Pusch, and Fienberg and Baehr all resorted to deep x-ray therapy before proceeding surgically, and in all of these cases radiation therapy failed to halt the disease. It would seem, therefore, that surgical intervention offers the most hope. We, therefore, recommend early removal of the lesions where this can be done. The value of surgical treatment, however, has not been fully established; this remains for future postoperative studies to determine. Enough is known about the pathology of the disease so that a diagnosis can be made. The emphasis should now be shifted to a study of the therapeutic results gained by surgical intervention.

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A SKULL-TRACTION APPARATUS

BY THEODORE H. VINKE, M.D., CINCINNATI, OHIO

A radically different and efficient type of skull-traction apparatus is designed to lock safely and securely in the skull, thus reducing to a minimum the possibility of its pulling out, once it has been properly inserted. The apparatus has an eccentric blade which fastens into an undercut hole in the outer cortex of the skull. The eccentric blade easily locks and unlocks the apparatus in the bone. To make this possible, the holes in the skull must be accurately placed and drilled. This is done by using a drill of predetermined length, which is placed in the bushings of the apparatus, so that it will drill the holes as perpendicular to the bone as possible, and also directly opposite each other. The use of these bushings provides great accuracy and precision in drilling the holes.

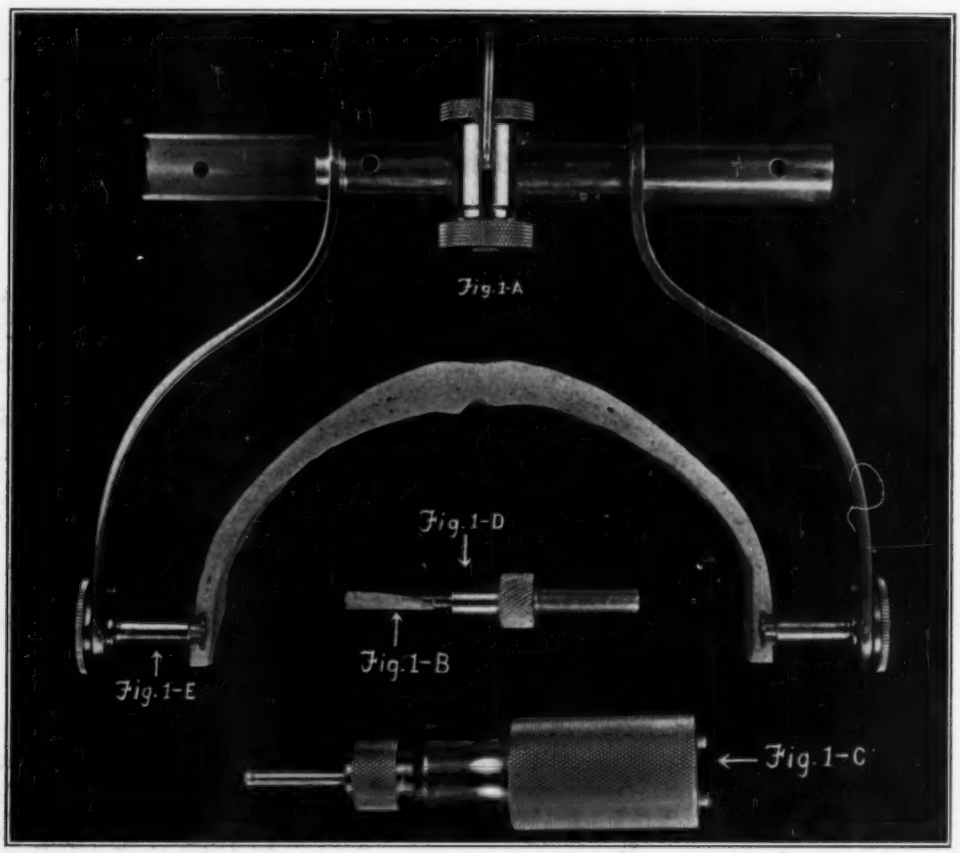

FIG. 1

Entire traction assembly in section of skull. (Drill and undercutting tool are included.)

The skull-traction apparatus and tools consist of three separate parts: first, the drill (Fig. *1-B*), second, the undercutting tool (Fig. 4), and third, the traction device (Fig. *1-A*). The drill (which should be used in a Jacob's chuck) should be of the right diameter to allow it to slide through the bushings on the side arms of the apparatus. A guard on the drill (Fig. *1-D*) is a simple and positive control over the depth to which the hole is drilled. The hole should be deep enough to go through the outer cortex of the parietal region of the skull, and should be placed about one inch above the ears in a relatively flat area of the skull. The bushings (Fig. *1-E*) are permanently attached to the apparatus and are larger

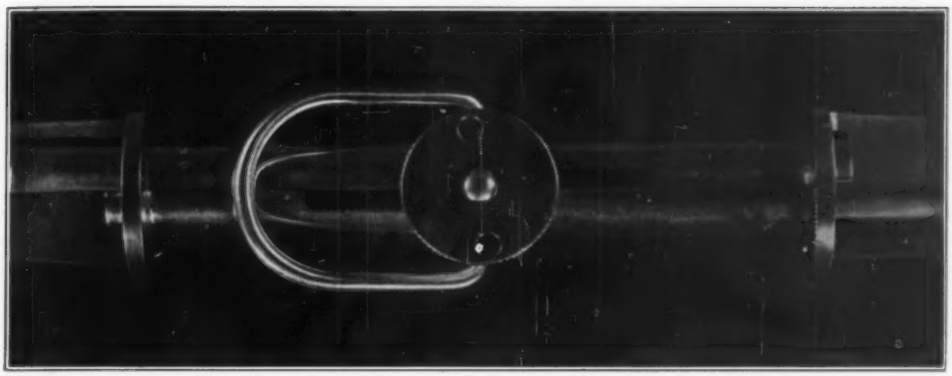

FIG. 2
Automatic centralization of traction.

than the holes in the bone, which prevents the locking pin from being forced through the skull by pressure or by accidental blows on the side of the frame.

The undercutting tool makes the bottom of the holes in the bone larger in circumference. The tool is so made that it cannot go any deeper than the hole made by the drill. Several successive cuts are made with this tool by a simple adjustment on the handle (Fig. 4). The holes are thoroughly flushed out with normal saline solution or sterile water and are then ready to accept the locking-pin device.

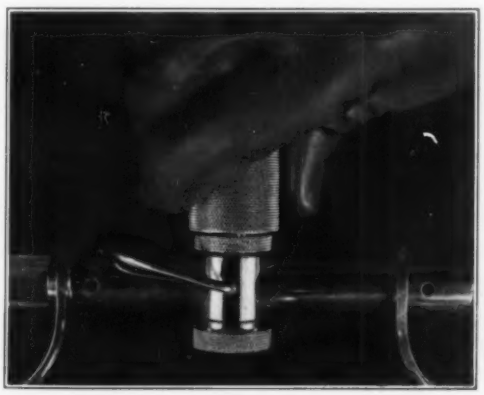

FIG. 3
Positive lock of control knob and frame.

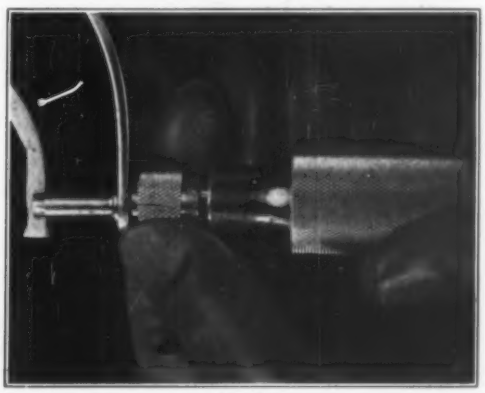

FIG. 4
Undercutting tool.

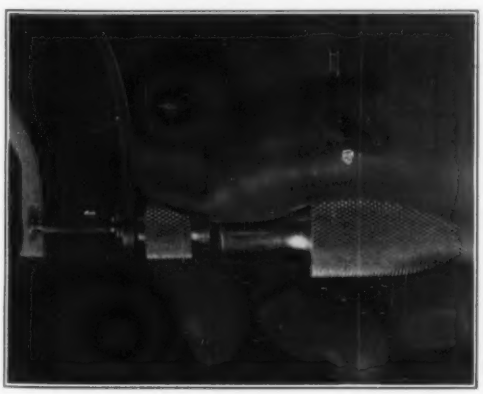

FIG. 5
Undercutting hole in skull.

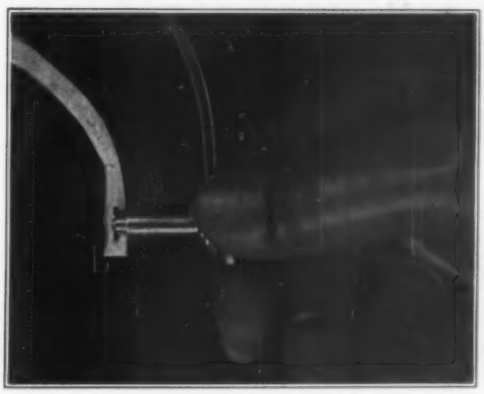

FIG. 6
Eccentric blade locked into skull.

The eccentric blade of the traction assembly is locked into position by turning the locking-pin blade 180 degrees. The locking-pin assembly must go in to the full depth of the hole, or until its inner face is in contact with the adjacent side of the frame. The above technique permits drilling the hole, undercutting it, and inserting the traction assembly into one side of the skull before changing the operating position.

The traction frame can be adjusted to the skull with the finger tips by one control knob. This knob automatically fixes the pull of the traction in the center of the apparatus. The frame (Fig. 1) closely conforms to the contour of the skull, in order to permit the patient to turn his head and to lie on either side. The frame is made of stainless, non-corrosive materials and weighs less than eleven ounces. It is rugged enough in construction to suspend the entire weight of the average patient's body.

The release mechanism is simple and effective, and facilitates easy removal of the apparatus from the skull. The entire apparatus can be dismantled for cleaning and sterilization, and re-assembled, without tools.

The procedure can be carried out by any qualified surgeon. It requires five simple manoeuvres, after an incision of three-quarters of an inch (1.8 centimeters) has been made and the bone has been exposed on both sides of the skull. They may be summarized as follows:

1. Place the apparatus in position with the bushings firmly against the skull, and lock it by turning the knob in Figure *1-A*.

2. Drill the hole. If one is worried about going through both cortices, a blunt probe can be placed in the bushing before the entire depth is drilled.

3. Undercut the hole.

4. Flush out the bone chips with water.

5. Insert the locking-pin device and turn it 180 degrees.

The advantages of the attachment are:

Apparatus is safely and positively locked into the skull.

Precision of location and alignment of holes in the skull are possible with bushings.

The use of an undercutting tool permits a deeper and more dependable attachment of the apparatus to the skull.

Traction pressure is distributed over a greater area of bone to prevent the apparatus from tearing out of the skull or damaging the brain.

There is simple and positive control over the predetermined depth of the drilling.

Drill bushings prevent the locking pins from being forced through the skull by pressure or an accidental blow on the side of the frame.

There is automatic centralization of the point of traction.

Adjustment of the traction frame to the skull of the patient can be made by the fingertips with one control knob.

Positive locking of the frame and centralization of the point of traction can be accomplished by one adjustment.

The entire traction apparatus weighs less than eleven ounces.

The shape of the frame conforms closely to the contour of the skull to permit turning of the patient's head and to minimize interference from the apparatus.

Stainless, non-corrosive materials are used throughout the apparatus.

There is a simple and effective release mechanism to facilitate the removal of the unit from the skull, regardless of bone growth.

The improved, time-saving technique permits drilling, undercutting of the hole, and complete attachment of the device to one side of the skull before changing the operating position.

Little special skill or experience is required to safely and positively attach the traction device to the skull.

The operation requires very little of the surgeon's time.

Editorials

The February 1948 number of *The Journal* is the first British issue under the new plan of co-publication. Representative of the orthopaedic surgery of the British nations, most of the clinical and scientific contributions, the proceedings, and the reports are from surgeons of the Commonwealth; there are notable papers from several other countries.

In every respect this number is outstanding. Its articles are being read and acclaimed by surgeons everywhere, who would keep pace with surgical developments,—not only because these contributions are progressive, but for their soundness. Readers of this number find strict adherence to fundamentals.

Among the technical articles, there is a critique of recurrent dislocation of the shoulder in nearly 500 cases, presented in six articles and a symposium; a review of mould arthroplasty of the hip is supplemented by a report of over 250 end results; a fundamental study of plasma-cell tumors is presented by a clinical pathologist and a radiologist; there is an analysis of penicillin therapy for hematogenous osteitis in children; an atlas of osteogenesis imperfecta is the first of an extraordinary series on general skeletal affections; and a number of other notable contributions are included. Every article is significant.

Surgical history and portraits of famous surgeons who have been great in their contributions to orthopaedic surgery have not been neglected.

From the standpoint of publication, this remarkable number is in every sense a work of art. It possesses unmistakably the stamp of the prototype.

To Sir Reginald Watson-Jones, the brilliant and indefatigable British Editor, to the able and hard-working British Editorial Board, and to our fellow orthopaedic surgeons throughout the British Commonwealth, thanks are due for the unusually high standard they have set.

Under the new plan of American-British Commonwealth co-publication, the international scope of *The Journal* has been extended; a fuller realization of aim has become possible. One may readily keep abreast of world progress in orthopaedic surgery today through the single publication. No surgeon can afford not to do so.

The first British issue has been warmly welcomed and is deeply appreciated by all who read *The Journal*.

THE DEVELOPMENT OF PRESENT-DAY KNOWLEDGE OF CONGENITAL DISLOCATION OF THE HIP

In view of what recent decades have contributed to the diagnosis and treatment of congenital dislocation of the hip, one is apt to forget that the roots of our knowledge are traceable to the dim past. After Hippocrates, who was aware of the condition and described it well (De Articulis, Chapter 46), there was a period of silence which lasted almost 2,300 years.

Great tribute should be given to Dupuytren (1826), who was the first to develop a comprehensive picture of the condition in the more modern sense. Pathological evidence, accumulated gradually in connection with therapeutic efforts, may be traced to the beginning of the nineteenth century. Feature after feature was added: the antetorsion of the head (Sandifort), the pathology of the muscles (Hutton), the hourglass constriction of the capsule (Bouvier), the changes of the acetabulum (J. Guérin), and finally the distinction between complete and incomplete dislocation (Parise). In the writings of Lorenz, in 1900 and 1920, we find an integration of all pathological evidence, augmented by his own investigations. It is not too much to say that the masterful monograph of Putti, in 1937, is the classic presentation of present-day knowledge of the pathology of this deformity.

The history of the treatment of congenital dislocation of the hip is more dramatic. Omitting such attempts as Kerkring's, who is credited as being the first to undertake the traction treatment, we may begin with Pravaz (1828), because his principle was gradual reduction by extension; over many byways and after errors, this finally ended up with the reduction manoeuvres of Paci and Lorenz.

It is interesting to note that, in the 1880's, the open operation had its first advocate in Poggi, and that it was further substantiated and improved by Hoffa. Lorenz, quick to recognize the importance of technical advances, elaborated on them, calling it the method of Hoffa-Lorenz. The bloodless reduction itself should be credited to Augustino Paci, whose first report appeared in 1880 and whose method parallels that of Lorenz, except for failure to maintain the proper end position, a point for which full credit is due to Lorenz.

It is a matter of common knowledge that the glowing reports of earlier surgeons on the end results of the bloodless treatment were not borne out by later statistics, and so it is not surprising to see a revival of the open method in 1920, with Galloway of Winnipeg as the foremost advocate. Although only a few surgeons at

this time accept the open method for universal application, we know from reports of Gill, Kidner, Howorth, and many others that it has a definite place and fills a need in cases in which the dislocation is irreducible or irretainable by the closed method.

The greatest advance of later years in treatment is the abduction method, and here the credit goes to Putti for insisting upon early diagnosis and for giving us the technique of the earliest reduction.

Late statistics certainly bear out the great superiority of the abduction treatment, if undertaken in the first year, over the bloodless method, even as it is modified at the present time. After the first year, we believe that the bloodless method of Paci and Lorenz, with Ridlon's modification of technique, still is the method of choice within a restricted age limit. At the same time one must concede to the open method those cases in which reduction cannot be attained or retained, owing to unsurmountable obstacles.

Since we have learned to relinquish the use of excessive force, the reduction trauma has been minimized and, with it, the subsequent degenerative changes of the femoral head.

These later years have produced three definite additions to the general principles of the treatment: first, that the early abduction treatment is the least traumatizing and, therefore, the most promising of all methods; second, that accurate concentric reduction of the head alone makes possible a proper formation of the acetabular roof; and third, that before weight-bearing is permitted, prolonged after-treatment for the development of the abductors and extensors is essential.

The more recent operative procedures of Colonna and those of Leveuf and Zahradníček likewise are based upon the postulates of concentric reduction and avoidance of reduction trauma.

At present, there is sufficient evidence to judge the merits of closed reduction on the basis of long-range observations. We still have to await the last word on the evaluation of open reduction as the method of choice. However, open reduction has established itself as an alternative, within limitations, in cases not responding to closed reduction.

Arthur Steindler, M.D.

CONGENITAL DISLOCATION OF THE HIP

The term "congenital dislocation of the hip", which is deeply rooted in the literature, does not accurately and comprehensively describe this deformity. Dislocation may not be present at birth, but may occur at some postnatal period. Complete luxation may never take place, but the deformity may persist as a subluxation. There has been an abnormal morphogenesis of the hip joint, which may or may not cause dislocation and which may or may not be remedied. The term "congenital dysplasia of the hip" more accurately describes this underlying defect in the growth processes.

The etiology of the condition is still under dispute. The genetic theory maintains that the departure from normal growth is due to some defect in the particular genes which are responsible for the development of the hip joint. The mechanical theory attributes the pathological changes to the operation of adverse mechanical forces during the period of growth *in utero*. Another suggestion is that constitutional conditions of the mother, during the period of pregnancy, may influence the growth processes in the foetus. Embryological studies have not as yet determined the etiological factors in congenital dysplasia of the hip. It may be possible that it is not necessary to attribute all cases to a single factor, inasmuch as there are so many variations in the form and the degree of the dysplasia and in the possibility of recovery.

Much advance has been made during recent years in knowledge of the pathology. The older descriptions, which are those usually found in textbooks, were made from the dissecting table and dealt largely with the secondary pathological anatomy of dislocation,—that is, with the changes which occur in the structures of the hip after dislocation. Knowledge of the primary changes which make dislocation possible or inevitable has been gained in the operating room. This has brought a much clearer understanding of the nature and of the elements of congenital dysplasia of the hip, and has guided us to better methods of treatment. The explanation of the primary pathological anatomy must be found in the etiological factors which produce the divergence from normal morphogenesis.

The prognosis depends upon the form and the degree of pathological divergence from the normal, and upon the ability of the structures of the hip to resume or to continue their growth toward the normal under favorable circumstances. Because there is a great diversity of anatomical deformity, it is illogical to expect uniform results from treatment. The most severe deformities have their origin in embryological or early foetal life, and are often accompanied by deformities of other parts of the body. They are incurable. The only available treatment may be a palliative operation at some appropriate time, to reduce the disability. Fortunately, these cases constitute a very small proportion of the total number of cases of dysplasia of the hip or even of the frank dislocations. If the deformities arise in later foetal life and, therefore, are not genetic in their origin, they are less severe and the prognosis for the development of a normal hip is favorable. This type is best represented by the so-called predislocations. Some of these probably recover spontaneously; many of them recover rapidly after birth as a result of a minimal term of treatment by abduction; but, at

best, in only a few of these cases do perfect hips develop, and only after prolonged treatment. There is some etiological factor or some growth factor that is obscure.

Insufficient study of the predislocations has been made in this country, largely because this condition is not diagnosed frequently enough at, or shortly after, birth. An accurate prognosis of postnatal dislocations cannot be made in any particular case at the time either open or closed reduction is accomplished. Insufficient accurate end-results studies have been made, either of open or closed reductions, to determine definitely the proportion of cases that are curable. Present indications are that it is not greater than one-fourth to one-third, if we accept as the criterion of cure the development of perfect or normal anatomical structures of the hip joint. There may be a prolonged period of normal function in many cases where anatomical perfection is wanting, but the continued mechanical wear and tear in an abnormal joint is almost certain to cause, sooner or later, the symptoms of traumatic arthritis. Many instances of this condition have been observed.

Our ideas concerning the treatment of congenital dislocation have changed greatly during the past fifty years. The recognition of predislocation in the newborn and of the dysplasias without dislocation that may be present at any age, the appreciation of the necessity of prolonged observation after reduction, the improvement of surgical technique and the origination of new surgical procedures, a better understanding of the primary and of the secondary pathological anatomy, and a clearer distinction between perfection and the varying degrees of imperfection of the end results have increased the extent and the precision of our knowledge, so that we are more able than formerly to determine what method of treatment should be employed at any time during the life history of a dysplasia or a dislocation.

In former years the orthopaedic surgeon saw and treated only the hips that were already dislocated. The dysplasias without dislocation were not recognized until after luxation had occurred. Now we know that early diagnosis and adequate treatment can prevent dislocation, although it should be realized that in not all cases do perfect hips result.

Various methods of bloodless reduction were employed, some of them forceful. In time it was recognized that severe force should not be employed to replace the femoral head within the acetabulum.

In many hips in which the surgeon considered the reduction to be successful at the end of one or two or three years, redislocation occurred at some subsequent time. Our present methods of careful and prolonged follow-up and our increased surgical knowledge and skill should prevent redislocations, and thereby greatly reduce the number of old irreducible dislocations that were formerly so prevalent.

The end results of bloodless reduction were so bad that some surgeons advocated the open reduction of all dislocations of the hip. No adequate statistics have ever been presented to prove that a higher percentage of perfect end results may be secured by open than by closed reduction. These surgeons thought that replacement of the femoral head within the acetabulum was all that was necessary to effect a cure. With our better knowledge of growth processes and of the pathological anatomy, we know that this is not necessarily true.

The old irreducible dislocation was formerly considered to be hopeless. It was later discovered that, by various types of osteotomies and by plastic bone surgery, much could be done to relieve these patients of their symptoms and to reduce their disability.

Still later, surgical procedures were devised to reduce those dislocations which could not be done bloodlessly, to stabilize the hips, and to construct a competent acetabulum for those which, after reduction, give evidence of a prolonged or irremediable dysplasia of the acetabular roof which permits subluxation. Whether or not the construction of an adequate acetabulum will lead to the formation of a perfect hip must depend, in large measure, upon the anatomy of the head and the neck of the femur, for not infrequently these structures and the capsular attachment to the neck are abnormal.

In the light of our present knowledge, we may state that most cases of congenital dysplasia of the hip without luxation are curable; that, of the more severe dysplasias which are marked by dislocation, only about one-third are curable; and that the nature of the deformities of bone and soft structures of the hip which are present when treatment is instituted determine in great measure the ultimate end result. If the surgeon is not always able to secure a perfect anatomical end result, he may do much to secure useful function.

A. Bruce Gill, M.D.

CORRECTION

An error was made in the paper by Dr. John Marquis Converse, "Plastic Repair of the Extremities by Non-Tubulated Pedicle Skin Flaps," which was published in the January 1948 issue of *The Journal*. On page 169, the first two lines of the second paragraph should read: "A widely known delayed flap is Gillies's tubed pedicle flap. The *disadvantage* of the tubed flap is the relatively long time required for its construction and transfer (Table I)."

BENJAMIN P. FARRELL
1870–1947

Dr. Benjamin P. Farrell, Professor Emeritus of Orthopaedic Surgery, died on December 27, 1947, after a protracted illness. Dr. Farrell was born at Pittsfield, Massachusetts, on May 22, 1870. He received his medical degree from the Long Island College Medical School, in 1904. Following this, he was an intern at the Newark City Hospital from 1904 to 1906. In 1906 he received an appointment at the New York Orthopaedic Hospital, to which institution he devoted his entire career until his retirement in 1940. Dr. Farrell was associated with Russell A. Hibbs and was his valued assistant during the period when Dr. Hibbs made so many contributions to orthopaedic surgery, including the operative treatment of joint tuberculosis and the development of the spine-fusion operation.

Dr. Farrell became Surgeon-in-Chief of the New York Orthopaedic Hospital in 1932, after the death of Dr. Hibbs. In 1918, the same year in which Dr. Hibbs became Professor of Orthopaedic Surgery, Dr. Farrell was appointed Assistant Professor. He later became Associate Professor, and then Professor and head of the department. He was Consulting Orthopaedic Surgeon to the French and Englewood Hospitals, and had a large private practice in New York City.

Dr. Farrell was a Fellow of the American College of Surgeons and The American Academy of Orthopaedic Surgeons, and a member of The American Orthopaedic Association, of which he was at one time Vice President.

In 1907, Dr. Farrell married Frances Lillian Mitchell, who died in 1942. They had no children.

He had a great capacity for making enduring friendships, and endeared himself to all of his associates and his many friends.

J. ARCHER O'REILLY
1879–1947

Dr. J. Archer O'Reilly of St. Louis, Missouri, a member of The American Orthopaedic Association, died in St. Louis on December 5, 1947.

In his death we have lost a great humanitarian, who devoted his life and interest to the handicapped. Born with a congenital defect, he ignored his own handicap so completely that neither his patients nor his acquaintances and friends thought of him as crippled. Dr. O'Reilly's creed was to help the crippled child and the crippled adult to get to the place where they could forget they were crippled.

He often stated: "The crippled child is the raw material from which a valuable citizen can be made. There is no shame in being handicapped; the only shame is in having a child needlessly deformed through neglect."

He was the son of the late Dr. Thomas W. O'Reilly, who practised for many years in St. Louis, and of Mary Archer O'Reilly. He received his A.B. from Harvard University in 1902 and his M.D. from Harvard Medical School in 1906. He served his internship at the Carney Hospital and returned to St. Louis to practise orthopaedic surgery. He became Professor of Orthopaedic Surgery at St. Louis University Medical School, Chief of the Orthopaedic Staff of the St. Mary's group of hospitals, and Associate Professor of Clinical Orthopaedic Surgery at Washington University Medical School, St. Louis. During World War I he was in charge of the Orthopaedic Staffs of Barnes Hospital and Children's Hospital in St. Louis. During World War II he was orthopaedic advisor to the draft boards. He was largely responsible for the organization and development of the Missouri and St. Louis Societies for Crippled Children. He had been President of the St. Louis Society since its founding, and served as President of the State group from 1930 to 1946, when he became chairman of the board; in October 1947, his son, J. Archer O'Reilly, Jr., became President. He had been a member of the Board of Trustees for the National Society for Crippled Children and Adults, Inc., since 1930, and was cited by this group in 1944 for distinguished service to the handicapped. He was a member of the advisory committee of the State Division of Rehabilitation, Department of Public Schools; a member of the board of the Occupational Therapy Workshop and of the St. Louis School for Occupational Therapy; and a member of the Board of Regents, State Cancer Hospital, Columbia, Missouri. From 1930 to 1935 he headed a Red Cross Committee on Vocational Rehabilitation.

At the time of his death he was Professor of Orthopaedic Surgery and Director of the Department at St. Louis University School of Medicine. He was orthopaedic surgeon to the De Paul Hospital in St. Louis and orthopaedic consultant to the Ranken-Jordan Convalescent Home for Crippled Children, St. Louis County.

He was a fellow of the American College of Surgeons, a diplomate of the American Board of Orthopaedic Surgery, a fellow of The American Academy of Orthopaedic Surgeons, and a member of the American Medical Association. He was a member of the St. Louis and Missouri Medical Associations, of the Southern Medical Association, and of the American Rheumatism Association, and a member of the House of Delegates of the American Medical Association. He was a former member of the Board of Governors of the American College of Surgeons. He was chairman of the Committee on Admissions of The American Orthopaedic Association for the year 1934–1935. He was a former chairman of the Orthopaedic Section of the American Medical Association.

Dr. O'Reilly is known for his work on behalf of the handicapped, and an interest which has spanned forty years of medical practice and earned for him national recognition as a friend of crippled children. He was a prolific writer for medical journals. He has consistently stressed the need of total rehabilitation for the handicapped,—education, emotional adjustment, and vocational training, as well as medicine and surgery.

As early as 1917 he was writing about poliomyelitis. In the early 1930's he began advocating private and public aid to victims of cerebral palsy, which he termed "the most neglected handicap"; 1946 saw the beginning of a national effort in this field, and in Missouri a state-wide program was started by the Missouri Society for Crippled Children. Throughout his career, he worked for better laws in Missouri to aid the handicapped, for greater state responsibility for the total rehabilitation of the handicapped, and for revision of insurance laws to encourage employers to hire handicapped persons.

Dr. O'Reilly was married in 1906, in Kingston, Massachusetts, to Jane Elliott Sever. Mrs. O'Reilly, three sons, and four grandchildren survive him. The sons are J. Archer O'Reilly, Jr., of St. Louis; Noel Sever O'Reilly of Toledo, Ohio; and Dr. Daniel Elliott O'Reilly of St. Louis, who plans to follow in the practice of orthopaedic surgery.

On March 27, 1947, the twentieth anniversary of the Missouri and St. Louis Societies for Crippled Children was marked by a testimonial dinner for Dr. O'Reilly. The Societies' tribute stated, in part:

"He has given his life to the promotion of better aid to crippled children throughout the land. He has never denied the plea of a parent or friend of a crippled child when his skill as a surgeon, or his humanitarian wisdom, could be of aid in any way. The crippled children of Missouri owe him a debt that our highest devotion to their welfare will scarcely repay."

LETTER TO THE EDITOR

In the October 1946 issue, an article appeared [Vol. 28, pp. 869–872] by Finch and Roberts, concerning two cases of epiphyseal coxa valga. This greatly interested me, but I am also very much puzzled in trying to harmonize the diagnosis of the position of the femoral head with the physical findings.

In Case 1, it was stated that the patient walked with an external-rotation deformity. Then, after manipulation and cast, she had an internal-rotation deformity of the left lower extremity of 10 degrees, but she still had 15 degrees of external rotation of the right lower extremity. It is evident from the roentgenograms that the head is displaced upward and laterally, but it is difficult to see how the epiphysis can be displaced anteriorly for the following reasons:

1. If the epiphysis was displaced anteriorly, an external-rotation deformity of the extremity would not be expected; however, we do get an external-rotation deformity (sometimes almost as much as 90 degrees) in the ordinary case of coxa vara where the epiphysis is displaced posteriorly.

2. Observation of the lesser trochanter shows that the femur is actually externally rotated, which could hardly be true if the epiphysis was displaced anteriorly.

3. It would be impossible from a study of flat roentgenograms of the head and neck alone, without lateral or stereoscopic roentgenograms, to tell whether the displacement was anterior or posterior. Seventy-five per cent. of the physicians fail to realize the limitations of flat roentgenograms and will conclude, when showed a flat roentgenogram of a fractured tibia, that the fragment casting the denser shadow is actually nearer to them.

Would not a more probable conclusion be that, in these two cases of coxa valga with slipped femoral epiphysis, the slipping occurred posteriorly, as usual, and not anteriorly, as suggested in the article?

T. Gordon Reynolds, M.D.
Glendale, California

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-first Annual Meeting of The American Orthopaedic Association will be held at the Chateau Frontenac, Quebec City, on June 3, 4, 5, and 6, 1948. This is to be a combined meeting of the British, Canadian, and American Orthopaedic Associations. The tentative program, as submitted by the Program Committee, is as follows:

Thursday, June 3

Morning Session

Aseptic Necrosis of Bone Following Trauma.
Edward L. Compere, M.D., Chicago, Illinois (A.O.A.).

Further Comments on Aseptic Necrosis of the Femoral Head, Sequel to Intracapsular Fractures.
W. W. Plummer, M.D., Buffalo, New York (A.O.A.).

Surgical Management of the Aseptic Necrotic Head of the Femur.
D. B. Phemister, M.D., Chicago, Illinois (A.O.A.).

Fractures of the Neck of the Femur Treated by Smith-Petersen Pin Plus Fibula Graft.
J. Patrick, F.R.C.S., Glasgow, Scotland (B.O.A.).

Subtrochanteric Limb Shortening.
Lawson Thornton, M.D., Atlanta, Georgia (A.O.A.).

Noon: First Executive Sessions of the American, British, and Canadian Orthopaedic Associations.

Afternoon Session

Arthrodesis of the Hip—Ischio-Femoral Method.
H. A. Brittain, F.R.C.S., Norwich, England (B.O.A.).

Osteoid Osteoma: A Clinical Pathological Study of a Series of Cases.
Malcolm Dockerty, M.D., Rochester, Minnesota (by invitation);
Ralph K. Ghormley, M.D., Rochester, Minnesota (A.O.A.).

Slipping of the Upper Femoral Epiphysis.
Beckett Howorth, M.D., New York, N. Y. (A.O.A.).

The Management of Incipient Epiphysiolysis of the Hip.
S. Kleinberg, M.D., New York, N. Y. (A.O.A.).

Roentgenographic Changes in Nailed Slipped Capital Femoral Epiphysis.
Armin Klein, M.D., Boston, Massachusetts (A.O.A.).

Subject to be announced.
Sten Friberg, M.D., Stockholm, Sweden (by invitation).

Friday, June 4

Morning Session

Osteo-Arthritis of the Hip Joint: Review of Over One Hundred Cases Treated by Arthroplasty.
Alexander Gibson, M.D., F.R.C.S., Winnipeg, Canada (A.O.A.).

Excision of the Femoral Head and Neck and Angled Osteotomy of the Femur in Ankylosis and Arthritis of the Hip.
J. S. Batchelor, F.R.C.S., London, England (B.O.A.).

A Follow-up Study of Results in Fascial Arthroplasties of the Knee.
J. S. Speed, M.D., Memphis, Tennessee (A.O.A.);
Philip C. Trout, M.D., Roanoke, Virginia (by invitation).

Arthroplasty of the Knee Joint—End Results.
J. Edward Samson, M.D., Montreal, Canada (C.O.A.).

Changes Observed in the Elastic Adipose Tissues with Advancing Years: Results of a Five-Year Study in the Harvard Medical School.
J. G. Kuhns, M.D., Boston, Massachusetts (A.O.A.).

End Results of Physiological Blocking of Flail Joints.
Alberto Inclán, M.D., Havana, Cuba (A.O.A.).

Afternoon Session

Fracture-Dislocation of the Pelvis.
F. W. Holdsworth, F.R.C.S., Sheffield, England (B.O.A.).

Developmental Coxa Vara.
A. B. LeMesurier, M.D., Toronto, Canada (A.O.A.).

Treatment of Some Irreducible Congenital Dislocations of the Hip.
Juan Farill, M.D., Mexico (A.O.A.).
Arthrography of the Hip.
F. C. Durbin, F.R.C.S., Exeter, England (B.O.A.).
Arthrodesis of the Ankle Joint.
W. E. Gallie, M.D., F.R.C.S., Toronto, Canada (A.O.A.).
Estrogens and Bone Formation in the Human Female.
Mary S. Sherman, M.D., Chicago, Illinois (by invitation);
C. Howard Hatcher, M.D., Chicago, Illinois (A.O.A.).
Subject to be announced.
Fuller Albright, M.D., Boston, Massachusetts (by invitation).

SATURDAY, JUNE 5

Morning Session

Congenital Discoid Meniscus.
I. S. Smillie, O.B.E., F.R.C.S., Edinburgh, Scotland (B.O.A.).
Results of Meniscectomy and the Theoretical Aspects of Operative Technique.
J. Charnley, F.R.C.S., Manchester, England (B.O.A.).
Knee-Joint Changes after Meniscectomy.
T. J. Fairbank, F.R.C.S., Reading, England (B.O.A.).
Treatment of Cervical Fracture and Fracture-Dislocation.
Wm. A. Rogers, M.D., Boston, Massachusetts (A.O.A.).
Treatment of Fracture-Dislocations of the Cervical Vertebrae by Skeletal Traction and Fusion—Results Ten Years Later.
W. G. Turner, M.D., Montreal, Canada (A.O.A.);
Wm. Cone, M.D., Montreal, Canada (by invitation).
Organization of an Accident Service.
W. Gissane, F.R.C.S., Birmingham, England (B.O.A.).
Presidential Address.
R. I. Harris, M.B., Toronto, Canada (A.O.A.).

Afternoon Session

Round-Table Discussion on Undergraduate Teaching in Orthopaedic Surgery.
Conducted by A. Bruce Gill, M.D., Philadelphia, Pennsylvania (A.O.A.).

SUNDAY, JUNE 6

Morning Session

Operative Approaches to the Shoulder Joint.
LeRoy C. Abbott, M.D., San Francisco, California (A.O.A.).
External Skeletal Fixation in Orthopaedic Surgery.
J. R. Naden, M.D., Vancouver, Canada (A.O.A.).
The Use of External Pin Fixation in Late Compound Fractures Due to War Wounds.
E. C. Janes, M.D., Hamilton, Canada (C.O.A.).
Treatment of Fractures of the Shaft of the Femur.
Edward Harlan Wilson, M.D., Columbus, Ohio (A.O.A.).
Denervation of the Elbow Joint for Relief of Pain—Preliminary Report.
James E. Bateman, M.D., Toronto, Canada (C.O.A.).
Case Report of Pedicled Nerve Graft with Discussion on the Applicability of Procedure.
F. G. St. Clair Strange, F.R.C.S., Folkestone, England (B.O.A.).
Elephantiasis Associated with Congenital Bands in Children.
A. W. Farmer, M.D., Toronto, Canada (A.O.A.).
Scoliosis Complicated with Paraplegia.
K. G. McKenzie, M.D., Toronto, Canada (by invitation);
F. P. Dewar, M.D., Toronto, Canada (C.O.A.).

The **National Foundation for Infantile Paralysis** will sponsor the First International Poliomyelitis Conference, to be held at the Waldorf-Astoria Hotel, New York, July 12 to 17.

The program will include scientific and technical papers on research and treatment of poliomyelitis, to be presented by professional authorities in the field from this country and abroad. In addition, there will be panel discussions on the various subjects.

The **Sociedad Española de Cirugía Ortopédica y Traumatología** has recently been organized with the following officers:

President: Dr. M. Salaverri, Bilbao;
Vice-President: Dr. R. San Ricart, Barcelona;
Secretary: Dr. M. Clavel, Murcia;
Vice-Secretary: Dr. C. González, Madrid;
Treasurer: Dr. A. Garaizábal, Madrid.

The official publication of this organization is *Cirugía del Aparato Locomotor* of which Dr. V. Sanchís Olmos is Editor.

The next meeting of this association will be held in Madrid in May. The principal subjects for discussion will be intramedullary nailing in fractures of the long bones and the treatment of scoliosis.

The Sixth International Assembly of the **International College of Surgeons** will be held in Rome, Italy, at the invitation of the Italian Government, during the week of May 16 to 23, 1948, under the presidency of Professors Raffaele Bastianelli and Raffaele Paolucci of Rome, and Mario Dogliotti of Turin. The Secretary of the Assembly is Prof. Giuseppe Bendandi of Rome. Attendance is not limited to the membership of the College; all surgeons in good standing in their medical organizations are invited. Scientific meetings, scientific and commercial exhibits, and visits to the Universities of Turin and Milan have been arranged, together with tours to other medical centers in Europe. A special exhibit of ancient texts on surgery is being arranged by Prof. Davide Giordano of Venice, Honorary President, under the active presidency of Prof. Adalberto Pazzini, Professor of History at the University of Rome. This extraordinary exhibit, dealing with ancient surgery, will be on display in the Vallicelliana Library in one of the historical buildings of the Vatican. Detailed information may be obtained from Dr. Max Thorek, General Secretary, 850 Irving Park Road, Chicago 13.

The Fourth Congress of **The International Society of Orthopaedic Surgery and Traumatology** will be held in Amsterdam on September 13 to 18, 1948. Headquarters for the Congress will be at the American Hotel.

The program has been arranged by Dr. Jean Delchef, Secretary General, and the two principal subjects for discussion will be:

1. The treatment of deforming arthritides of the hip. (Led by Professors Mathieu and Padovani, Paris.)
2. Occult traumatisms of the vertebral column. (Led by Mr. E. A. Nicoll, Manchester, England.)

These topics will also be discussed by other distinguished orthopaedic surgeons including Professors Zahradníček (Czechoslovakia), La Chapelle (The Netherlands), Delchef (Belgium), Wiberg (Sweden), Böhler (Austria), Pais (Italy), Inclán (Cuba), San Ricart (Spain), and Smith-Petersen (U.S.A.). Papers and motion pictures on other subjects will also be presented. Anyone who wishes to present a paper or motion picture should submit the title and a short summary to Dr. Delchef before June 30, 1948.

Arrangements have been made for about 500 rooms for the members and guests of the Society during the time of the Congress. Due to congestion in the city, reservations should be made early and should be sent directly to Dr. J. D. Mulder, Vondelstraat 75, Amsterdam, Holland.

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Fifteenth Annual Convention of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, January 24, 25, 26, 27, 28 and 29, 1948, under the presidency of Dr. Rex L. Diveley. The Convention was the largest in the history of The Academy. The Audio-Visual Program, under the chairmanship of Dr. Charles N. Pease, was well arranged and attracted large audiences. The Instructional Courses, under the chairmanship of Dr. Walter P. Blount, provided a wide choice and were well attended. The Scientific Program was arranged by the Program Committee, of which Dr. T. Campbell Thompson was Chairman. This was presented on the afternoon of Monday, January 26, at the morning and afternoon sessions of Tuesday and Wednesday, and at the morning session on Thursday, January 29, as follows:

Monday, January 26

Afternoon Session

Occurrence and Management of Reflex Sympathetic Dystrophy—Causalgia of the Extremities.
James W. Toumey, M.D., Boston, Massachusetts.
Discussion: Harold R. Bohlman, M.D., Baltimore, Maryland.

The Use of Iliac-Bone Grafts in Orthopaedic Surgery.
I. S. McReynolds, M.D., Houston, Texas.
Discussion: Leonard F. Bush, M.D., Danville, Pennsylvania (by invitation).
Fractures of the Carpal Scaphoid.
H. Osmond Clarke, F.R.C.S., London, England (by invitation).
Delayed Bone Graft in the Treatment of Congenital Pseudarthrosis.
John R. Moore, M.D., Philadelphia, Pennsylvania.
Discussion: William T. Green, M.D., Boston, Massachusetts;
Dallas B. Phemister, M.D., Chicago, Illinois.
Short First Metatarsal—Its Incidence and Clinical Significance.
T. Beath, M.D. (by invitation), and R. I. Harris, M.B., Toronto, Canada.
Discussion: Robert Bingham, M.D., Riverside, California (by invitation);
R. Plato Schwartz, M.D., Rochester, New York.

TUESDAY, JANUARY 27

Morning Session

Legg-Perthes Disease—A Method of Conservative Treatment.
Maurice M. Pike, M.D., Hartford, Connecticut.
Discussion: M. Beckett Howorth, M.D., New York, N. Y.;
A. Bruce Gill, M.D., Philadelphia, Pennsylvania.
The Relationship between Congenital Subluxation and Congenital Dislocation of the Hip.
Vernon L. Hart, M.D., Minneapolis, Minnesota.
Discussion: Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
H. Relton McCarroll, M.D., St. Louis, Missouri.
Treatment of the "True" Congenital Luxation of the Hip. Results of the Open Reduction.
Professor Jacques Leveuf, Paris, France.
Aspects of Physical Reconditioning.
Marcus J. Stewart, M.D., Memphis, Tennessee (by invitation).
Vocational Rehabilitation.
Michael J. Shortley, Washington, D. C. (by invitation).
Rehabilitation of the Severely Handicapped.
Henry H. Kessler, M.D., Newark, New Jersey.
Discussion: A. R. Shands, M. D. Wilmington, Delaware;
Rufus H. Alldredge, M.D., New Orleans, Louisiana;
Frank Stinchfield, M.D., New York, N.Y., *Chairman*.

Afternoon Session

Dupuytren's Contracture: A Report of Fourteen Cases of Combined Palmar and Plantar Lesions.
J. Vernon Luck, M.D., Los Angeles, California.
Discussion: Arthur Steindler, M.D., Iowa City, Iowa;
H. W. Meyerding, M.D., Rochester, Minnesota.
Criteria for Spine Fusion Following Removal of Protruded Nucleus Pulposus.
Guy A. Caldwell, M.D., and William B. Sheppard, M.D., New Orleans, Louisiana.
Vascular Complication of Disc Surgery.
Edward C. Holscher, M.D., St. Louis, Missouri (by invitation).
Discussion: Raymond E. Lenhard, M.D., Baltimore, Maryland;
James W. Shumate, M.D., San Francisco, California;
Joseph S. Barr, M.D., Boston, Massachusetts;
William B. Sheppard, M.D., New Orleans, Louisiana.
The Problem of the Primary Curve in Idiopathic Scoliosis.
John R. Cobb, M.D., New York, N. Y.
Changing Concepts in Scoliosis.
W. H. Von Lackum, M.D., New York, N. Y.
Discussion: Albert B. Ferguson, M.D., Brookline, Massachusetts (by invitation);
Albert C. Schmidt, Milwaukee, Wisconsin;
Henry F. Ullrich, M.D., Baltimore, Maryland.

WEDNESDAY, JANUARY 28

Morning Session

The Use of Skeletal Traction in the Treatment of Fractures of the Femur.
Edward M. Winant, M.D., New York, N. Y.

Open Reduction and Internal Fixation of Long-Bone Fractures.
Harrison L. McLaughlin, M.D., New York, N. Y.
External Skeletal Fixation in the Treatment of Tibial Fractures.
John R. Naden, M.D., Vancouver, British Columbia.
Discussion: William Darrach, M.D., New York, N. Y. (by invitation);
H. Osmond Clarke, F.R.C.S., London, England (by invitation);
H. Earle Conwell, M.D., Birmingham, Alabama;
Mather Cleveland, M.D., New York, N. Y., *Chairman*.
Surgical Treatment of Non-Union of Long Bones.
Dr. Robert Merle D'Aubigne, Paris, France.
Presidential Address.
Rex L. Diveley, M.D., Kansas City, Missouri.

Afternoon Session

The Cervical Syndrome as a Causative Factor in Certain Shoulder Disabilities.
Ruth Jackson, M.D., and Margaret Watkins, M.D., Dallas, Texas.
Discussion: Arthur G. Davis, M.D., Erie, Pennsylvania;
Arthur Steindler, M.D., Iowa City, Iowa.
Aseptic Necrosis of the Femoral Head.
Joseph M. Regan, M.D. (by invitation), and Ralph K. Ghormley, M.D., Rochester, Minnesota.
Discussion: William Cooper, M.D., New York, N. Y.;
Dallas B. Phemister, M.D., Chicago, Illinois.
Early Effects of Partial Denervation of the Hip for Relief of Pain in Chronic Arthritis of the Hip.
Benjamin E. Obletz, M.D., Buffalo, New York.
Discussion: Emanuel B. Kaplan, M.D., Bronx, New York;
J. Albert Key, M.D., St. Louis, Missouri.
Hamstring-Tendon Transplantation for the Relief of Quadriceps Paralysis in Residual Poliomyelitis.
J. R. Schwartzmann, M.D. (by invitation), and C. H. Crego, Jr., M.D., St. Louis, Missouri.
Discussion: Theodore H. Vinke, M.D., Cincinnati, Ohio;
Frederick J. Fischer, M.D., Detroit, Michigan.
Traumatic Proliferations of Fibrocartilage with Ossification in the Genesis of Spondylitis Deformans and Traumatic Myositis Ossificans.
Edwin F. Hirsch, M.D., Chicago, Illinois (by invitation).
Discussion: Fremont A. Chandler, M.D., Chicago, Illinois;
C. Howard Hatcher, M.D., Chicago, Illinois (by invitation).

THURSDAY, JANUARY 29

Morning Session

The Status of Lumbosacral Fusion. An Operation of Transfacet Mortised Bone Block.
Earl D. McBride, M.D., Oklahoma City, Oklahoma.
Arthrodesis of the Spine. An Ankylosing Method Permitting Early Ambulation.
Roger Anderson, M.D., Seattle, Washington; Ivan Loughlen, M.D., Seattle, Washington (by invitation); and Pen-Chien T'ung, M.D., Nanking, China (by invitation).
The Flexion Block Fusion with Screw Fixation of Facets.
O. Anderson Engh, M.D., Washington, D. C.
Discussion: Lenox D. Baker, M.D., Durham, North Carolina;
L. Ramsay Straub, M.D., New York, N. Y.;
Austin T. Moore, M.D., Columbia, South Carolina;
Alan DeForest Smith, M.D., New York, N. Y.;
Duncan C. McKeever, M.D., Houston, Texas;
David M. Bosworth, M.D., New York, N. Y.
Acute Anterior Dislocation of the Shoulder.
Toufick Nicola, M.D., Montclair, New Jersey.
Posterior Dislocation of the Shoulder.
John C. Wilson, M.D., and Francis McKeever, M.D., Los Angeles, California.
Discussion: Harrison L. McLaughlin, M.D., New York, N. Y. (by invitation);
N. J. Giannestras, M.D., Cincinnati, Ohio;
John J. Fahey, M.D., Chicago, Illinois.
Executive Sessions were held at noon on Tuesday and on Thursday.

At the Instructional Course dinner on Saturday night, an "Information Please" program was presented which was both instructive and entertaining. On Tuesday evening, a stag smoker was held in the Red Lacquer room, which enabled all present to meet the distinguished foreign guests.

The Annual Dinner was held on Wednesday evening. The brief program included introduction of the distinguished foreign guests; the presentation of the presidential medallion was made to Dr. Rex L. Diveley by Past-President Dr. J. E. M. Thomson. At this dinner the awards for scientific exhibits and motion pictures were made as follows:

Class I: For Originality of Presentation.

1. Harry B. Macey, M.D., Temple, Texas (Scott and White Hospital), "A Plastic Procedure for Treatment of Disabling Lymphoedema of the Extremities".
2. Garrett Pipkin, M.D., Kansas City, Missouri, "Lesions of the Plica Synovalis: An Intra-Articular Disability of the Knee".
3. W. H. McGaw, M.D., H. E. Snedden, M.D., and J. M. Muckley, M.D., Cleveland, Ohio, "Pneumarthrograms of the Knee: A Diagnostic Aid in Internal Derangements".

Class II: For Scientific Value.

1. George Gennett, M.D., and Anthony F. De Palma, M.D., Philadelphia, Pennsylvania (Jefferson Medical College, Departments of Anatomy and Orthopaedics), "The Variational Anatomy of the Shoulder Joint, Especially of the Labrium Glenoidale, the Glenohumeral Ligaments, and the Associated Bursae".
2. Paul R. Lipscomb, M.D.; A. M. McKelvie, M.D.; A. C. Walsh, M.D.; and J. D. Barger, M.D., Rochester, Minnesota (Mayo Clinic), "Histologic Demonstration of Alkaline Phosphatase in Relation to Osteogenesis".
3. Leonard F. Bush, M.D.; William H. Von Lackum, M.D.; C. Zent Garber, M.D.; and James P. Miller, M.D., New York, N. Y. (New York Orthopaedic Hospital), "Bone Bank".

Class III: For Clinical Value.

1. John R. Cobb, M.D., New York, N. Y. (Hospital for Special Surgery), "Scoliosis: A Study of the Mechanical Principles in Idiopathic Scoliosis".
2. Vernon L. Hart, M.D., and Wesley H. Burnham, Minneapolis, Minnesota, "The Relationship Between Congenital Subluxation and Congenital Dislocation of the Hip".
3. David Goldberg, M.D., Springfield, Massachusetts, "Metacarpal Fractures: A New Instrument for the Maintenance of Position after Reduction".

Awards: Gadget Exhibit.

1. Howard B. Shorbe, M.D., Oklahoma City, Oklahoma (McBride Clinic): Convex Saddle Frame for Spine Operations.
2. Homer H. Stryker, Kalamazoo, Michigan: Oscillating Bone Saw.
3. Fremont A. Chandler, Chicago, Illinois (Research and Educational Hospitals):
    1. *a.* Skin Resection and Traction Cast.
       b. Negative Pressure.
    2. Leg Elevation.
    3. Drill.
    4. Retractor.
    5. Anaesthetic Pads for Spinal Operations.

Prizes were awarded to the following men, whose motion-picture productions appeared on the Audio-Visual Program:

Gold Medal—Harry B. Macey, "A Plastic Procedure for Treatment of Disabling Lymphoedema of the Extremities".

Certificate of Merit—Professor H. J. Seddon and A. E. Barclay, "Cineradiography of Abnormal Joints".

Certificate of Merit—J. A. Leo Walker, "Fusion of the Ankle Joint".

Honorable Mention—Joseph E. Markee, "The Anatomy of the Plantar Aspect of the Foot".

Honorable Mention—Alejandro Velasco Zimbron and Alberto Palacio Gomez, "Osteosynthesis of Fracture of the Neck of Femur by Pegging with Fibular Bone Splints".

At this dinner diplomas were presented to the following newly elected Fellows by President Rex L. Diveley and Dr. J. Warren White, Chairman of the Membership Committee.

Stanley Sisco Atkins, M.D., Asheville, North Carolina
Robert G. Brashear, M.D., Knoxville, Tennessee
John R. Buchanan, M.D., Youngstown, Ohio
Felix L. Butte, M.D., Dallas, Texas
James J. Callahan, M.D., Chicago, Illinois
Alfred V. Cherry, M.D., Buffalo, N. Y.
James H. Cherry, Asheville, North Carolina
Mark B. Coventry, M.D., Rochester, Minnesota
Patrick C. Doran, M.D., Akron, Ohio
Paul H. Dubé, M.D., Lakewood, Ohio

Daniel B. Eck, M.D., East Orange, New Jersey
Charles L. Farrington, M.D., St. Petersburg, Florida
George G. Fox, M.D., Meriden, Connecticut
Morris S. Friedman, M.D., South Bend, Indiana
Joseph D. Godfrey, M.D., Buffalo, New York
Meyer Zachary Goldner, M.D., Minneapolis, Minnesota
Irvin E. Hendryson, M.D., Denver, Colorado
Alan B. Hirschtick, M.D., Chicago, Illinois
Irwin B. Horwitz, M.D., St. Louis, Missouri
Louis W. Jones, M.D., Wilkes-Barre, Pennsylvania
Graham A. Kernwein, M.D., Minot, North Dakota
Byron B. King, M.D., Benton Harbor, Michigan
Joseph C. Lawrence, M.D., Evansville, Indiana
Louis J. Levy, M.D., Fort Worth, Texas
F. O. McGehee, M.D., Houston, Texas
John G. Manning, M.D., Pasadena, California
Carl D. Martz, M.D., Indianapolis, Indiana
John L. Marxer, M.D., Portland, Oregon
Matthew Mendelsohn, M.D., Washington, D. C.
Benjamin S. Meyer, M.D., Birmingham, Alabama
James Walter Miller, M.D., Seattle, Washington
Moore Moore, Jr., M.D., Memphis, Tennessee
Roy I. Peck, M.D., Philadelphia, Pennsylvania
William S. Perham, M.D., New Haven, Connecticut
Robert B. Portis, M.D., Beverly Hills, California
Frederic W. Rhinelander, M.D., San Francisco, California
Albert H. Rodi, M.D., Los Angeles, California
Myron G. Rosenbaum, M.D., Albuquerque, New Mexico
Olav Rostrup, M.D., Edmonton, Alberta, Canada
Francis B. Roth, M.D., New York, N. Y.
Carter R. Rowe, M.D., Boston, Massachusetts
Ralph E. Rowen, M.D., Little Rock, Arkansas
Americo Savastano, M.D., Providence, Rhode Island
Louis Scheman, M.D., Chicago, Illinois
Lee C. Schlesinger, M.D., New Orleans, Louisiana
William J. Schnute, M.D., Chicago, Illinois
Harold Seidenstein, M.D., New York, N. Y.
Frank B. Smith, M.D., Portland, Oregon
William F. Stanek, Jr., M.D., Denver, Colorado
John B. Stevens, M.D., Syracuse, N. Y.
Lee Ramsay Straub, M.D., New York, N. Y.
David R. Telson, M.D., Brooklyn, N. Y.
Arthur A. Thibodeau, M.D., Boston, Massachusetts
Albert A. Tisdale, M.D., Austin, Texas
William J. Tobin, M.D., Washington, D. C.
Henry F. Ullrich, M.D., Baltimore, Maryland
Francis P. Walsh, M.D., Detroit, Michigan
Edgar H. White, M.D., Cincinnati, Ohio
Edward M. Winant, M.D., New York, N. Y.

It was announced that the following had been elected to Corresponding Membership:

A. Montagne, M.D., Lima, Peru
Harry Romney, M.D., Havana, Cuba
Vaclav Tosovsky, M.D., Sokolska, Czechoslovakia
Jaroslav Slavik, M.D. Italska, Czechoslovakia
Jan Cervenansky, M.D., Bratislavia, Czechoslovakia
Med A. Monberg, M.D., Copenhagen, Denmark

The following were elected to Honorary Membership:

H. Osmond Clarke, F.R.C.S., London, England
Murray Copeland, M.D., Washington, D. C.

The following members were transferred to Emeritus Membership:

Alfred Leslie Craig, M.D., Honolulu, Hawaii

John Dunlop, M.D., Pasadena, California
Alonzo Myers, M.D., Charlotte, North Carolina

The officers of the Academy for 1948 are:
President: Myron O. Henry, M.D., Minneapolis, Minnesota
President-Elect: Mather Cleveland, M.D., New York, N. Y.
Vice-President: Allen F. Voshell, M.D., Baltimore, Maryland
Secretary: Harold B. Boyd, M.D., Memphis, Tennessee
Treasurer: Fremont A. Chandler, M.D., Chicago, Illinois
Librarian-Historian: Edward L. Compere, M.D., Chicago, Illinois.

The Sixteenth Annual Convention will be held at the Palmer House, Chicago, January 22–27, 1949, under the presidency of Dr. Myron O. Henry.

SUGGESTED PLANS FOR BETTER COOPERATION OF ORGANIZATIONS CONCERNED WITH APPROVAL OF RESIDENT TRAINING PROGRAMS

BY GUY A. CALDWELL, M.D., NEW ORLEANS, LOUISIANA*

All organizations concerned with graduate training realize a need for closer coordination of their activities. The American College of Surgeons, the Council on Medical Education and Hospitals of the American Medical Association, and the specialty boards are most directly concerned with inspections and approval of services for specialty training. Each of these is interested in providing the best possible graduate training in the specialties and, in general, they have similar standards and requirements specified for the hospitals and their staffs to meet. However, as the scope of activity of the various organizations has broadened, there have developed some overlapping and duplication of efforts. Some hospital services have been inspected by a representative of the American College of Surgeons and subsequently by someone from the Council on Medical Education and Hospitals. Sometimes the opinions of the two inspectors have differed, and the lists of approved services which were published, one by the American College of Surgeons and the other by the American Medical Association, therefore, have not always been uniform. Some residencies approved by the College were not recognized by the Council, and *vice versa*, all of which has been confusing to prospective trainees and embarrassing to the certifying boards.

The number of approved services has increased rapidly during the past three years, and many of them were approved only on a temporary basis. Therefore, at this time, there is need for review or reinspection of nearly all recognized services. So few qualified inspectors are available to the Council and College, that it may be several years before all the needed inspections can be completed. Under these conditions, the American Board of Surgery and the Joint Committee on Graduate Education of The American Academy of Orthopaedic Surgeons and The American Orthopaedic Association obtained the consent of the Council on Medical Education and Hospitals to have some of their own diplomates visit hospitals with tentatively approved services and make reports on the present status of these services.

By sending out a large number of qualified men simultaneously, these two boards obtained a nationwide survey of the training in surgery and orthopaedic surgery in a few months' time. Reports made by these diplomates, acting as inspectors, were of special interest to the Council because, for the first time, the reports were made by men capable of judging the quality of surgery performed, the teaching ability of the staff, and the effectiveness of the training program from the viewpoint of the residents.

As a result of the efforts made by the Joint Committee on Graduate Education and the American Board of Surgery, a meeting was held in Chicago, on February 21, of the Council on Medical Education and Hospitals, the trustees of the American Medical Association, a committee of regents of the American College of Surgeons, the secretary of the Medical Advisory Board, and representatives of the American Boards of Surgery and Orthopaedic Surgery. The purpose of the meeting was to set up uniform standards, to eliminate duplication of effort and expenditure of funds, to pool the reports of inspections, and to make the resultant information available to all parties concerned.

An excellent spirit of cooperation was manifested by all present and the meeting culminated in the designation of a committee of seven, representing all the related organizations, who are to formulate recommendations and working plans for a unified service and common standards. Their plans will also provide for more frequent and competent inspections of resident-training services, and should eliminate conflicting reports and lists.

Orthopaedic surgeons may be interested to know that much of this constructive movement has been the outgrowth of the excellent work of the Joint Committee on Graduate Training. The reports of the early work and inspections done by this Committee three years ago have led to the recent surveys and widespread interest in future planning.

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Book Reviews

CHRONIC STRUCTURAL LOW BACKACHE DUE TO LOW-BACK STRUCTURAL DERANGEMENT. R. A. Roberts, B.Sc., M.B., Ch.B., D.M.R.E. London, H. K. Lewis and Co., Ltd., 1947. 45 shillings.

Under this descriptive but awkward title, the author discusses the various developmental defects of the lower back as etiological factors in the production of low-back pain and sciatic pain. The studies upon which the work is based were made mostly in a temporary base hospital, serving the Middle East Forces. This accounts for the imperfections in reproduction of many of the roentgenographic illustrations, but the author has made tracings of the original films which demonstrate the defects discussed.

Case histories are presented in the discussions of the different defects, and the importance of tracing the histories back to childhood is emphasized, as most of them divulge recurring attacks of back disability over a period of many years.

The theory is advanced that the bone defect of the pars interarticularis of the neural arch, known also as spondylolysis and separate neural arch, is not a defect of ossification of that part, but rather a linear de-ossification due to overstrain from the upright posture, with consequent changes in the soft parts similar to those occurring in so-called march fractures. The author describes a softening with downward and forward sagging of the arch, with roentgenographic appearance of a translucent striation across it. He mentions the possibility of re-ossification of the part with formation of an S curve in the bone.

Readers who have examined a number of macerated specimens of this defect, particularly the unilateral ones, and have noted the facility with which march fractures heal, will hesitate to accept this theory.

Supernumerary ossicles which cause widening of the pars interarticularis of the upper lumbar vertebrae are thought to represent bridging of the de-ossification defects. In the illustrations they suggest irregular calcifications of the interspinal ligaments. Defects in ossification of the articular processes are mentioned as of frequent occurrence and of major clinical importance. The various types are well illustrated.

Diminished intervertebral space is considered a frequent cause of back pain, particularly when accompanied by sclerosis and lipping of the adjacent vertebral bodies, which suggest prolonged mechanical irritation.

In Chapter VIII are discussed backaches without recognizable roentgenographic changes. These are often associated with genito-urinary, psychiatric, rheumatic, or gastro-intestinal disturbances. It is argued that often such disturbances are the result, rather than the cause, of mechanical overstrains and soft-tissue abnormalities of the back, with involvement of nearby sympathetic ganglia.

The author concludes that structural derangements of the back give rise to backache only as they affect stability of the part, thereby throwing excessive strain on the ligaments and muscles with consequent oedema, exudation, adhesions, and contractures.

Treatment of backache due to structural defects is predicated on the assumption that the ache is the result of mechanical strain, consequent upon the upright posture. The first objective is, therefore, reduction of this strain by flexion and balancing of the lumbar curve, and the restoration of tone to the muscles that maintain it. Temporary support, exercises, and occasionally manipulation to free adhesions are the principal suggestions. When there is definite evidence of permanent instability or when disability is progressive, surgical stabilization of the part is indicated.

Two operative procedures are mentioned,—the bone-graft fusion and Dandy's curettage of the intervertebral disc. Since Dandy's discussion of spondylolisthesis was based on Neugebauer's essay on that subject, published in 1892, it has not won much credence.

In the closing chapter, the frequency of the faulty diagnosis of malingering is stressed and case histories are presented, showing the injustice done many individuals through failure to study each patient thoroughly. Actual malingering is rarely found, if a careful study is carried out.

BRITISH SURGICAL PRACTICE. Volume I. Edited by Sir Ernest Rock Carling, F.R.C.S., F.R.C.P., and J. Paterson Ross, M.S., F.R.C.S. London, Butterworth and Co., Ltd., 60 shillings (25 pounds for the set); St. Louis, C. V. Mosby Company, 1947. $15.00 ($125.00 for the set).

British Surgical Practice comprises a series of eight volumes, plus an index, dealing with surgical diagnosis and surgical technique. Volume I is now available, Volume II will be ready very soon, and the remaining volumes are scheduled for release during 1948 and 1949. The completed set is expected to contain from 4,200 to 5,000 pages.

The subject matter, which covers the field of surgical practice, is arranged alphabetically, so that Volume I begins with Abdominal Emergencies and concludes with the Autonomic Nervous System. A long list of eminent surgeons have contributed to Volume I. In general, the articles are classified as to etiology, surgical

and morbid anatomy, the clinical picture, differential diagnosis, treatment, and results of treatment. Each volume has an index; upon completion of the set, an analytical index will be published as a separate volume.

In order that the set may be kept up to date, an annual supplement will be published, correlated with the original volumes by a key number.

A Manual of Fractures and Dislocations. Ed. 2. Barbara Bartlett Stimson, A.B., M.D., Med. Sc.D., F.A.C.S. Philadelphia, Lea and Febiger, 1947. $3.25.

The second edition of this handbook on the diagnosis and treatment of fractures and dislocations is written in a concise and practical manner, and is useful for medical students and practitioners who do not specialize in the treatment of these injuries. The author's experience has been broad, as, for many years, she has been associated with a large teaching fracture service in New York City; she bases her opinions on the records of more than 21,000 fractures and dislocations, many of which she herself has observed and treated. The author admits that there are frequently many ways to treat the individual fracture, but she has selected, by and large, those methods which, in the experience of the fracture clinic of the Presbyterian Hospital-Columbia Medical Center, have proved most effective.

A few points should be questioned. The illustration of Russell traction does not appear to be quite correct; internal fixation of fractures does not necessarily shorten the period of external fixation; internal fixation does not speed healing of fractures,—rather, in some cases it may retard healing. There is no real substitute for callus. The pillow and sideboard splint should be advocated for the temporary splinting of fractures below the knee.

The chapters on the healing of bone and on the principles of fracture treatment are particularly worth while, and can be read with benefit by all interested in the management of fractures and dislocations.

Minor Surgery. Ed. 6. Frederick Christopher, B.S., M.D., F.A.C.S. Philadelphia, W. B. Saunders Company, 1948. $12.00.

The latest edition of this textbook presents a thorough revision of that published in 1944; many sections have been rewritten and new sections have been added. Increasing importance is ascribed to the sulfonamides and to antibiotics, and information gained from experience in World War II has been incorporated in the discussions of such subjects as burns, varicose veins, and artificial respiration. The sections on wound healing, fractures of the carpal scaphoid, Colles's fracture, march fractures, skin-grafting, and others, have been amplified.

The final chapter, "The Surgical Intern", contains much practical information and has long been a useful guide for interns. Each chapter closes with an extensive bibliography.

In its scope of subject matter, this continues to be one of the foremost surgical texts for students, interns, and general practitioners. The field of minor surgery is vast and always increasing.

Diseases of the Joints and Rheumatism. Kenneth Stone, D.M. (Oxon.), M.R.C.P. London, William Heinemann, Ltd.; New York, Grune and Stratton, 1947. $6.50.

Anyone interested in the diseases of the joints and rheumatism would do well to peruse in a careful manner this book by Kenneth Stone. It contains a great deal of information, interestingly presented.

The chapter on "General Anatomy and Physiology of the Joints" is well done. It does, however, lack complete information concerning synovial fluid,—particularly the interpretation of variations in cellular and chemical findings.

The author uses in an effective style the original descriptions by many early writers. This gives one the impression that the work was studiously compiled.

All medical orthopaedists and orthopaedic surgeons should read Chapter IV, "Rest and Movement". One may not agree with all that Stone says, but the fundamental therapeutic principle is correct. Its application is the thing to learn.

A lack of close association and exchange of ideas between the medical orthopaedists and the orthopaedic surgeons tends to delay the diffusion of knowledge; this is obvious in the chapter on "Painful Hips". No mention is made of mold arthroplasty as a method of relieving the pain in these conditions.

The concept and use of the terms "rheumatism" and "fibrositis" is presented clearly, and perusal of the book gives a better understanding and a little more confidence to the physician who confronts a patient complaining of rheumatism.

Regional Orthopaedic Surgery and Fundamental Orthopaedic Problems. The American Academy of Orthopaedic Surgeons. James E. M. Thomson, M.D., Editor. Ann Arbor, Michigan, J. W. Edwards, 1947. $6.00.

This volume of lectures given during the Instructional Courses of The American Academy of Orthopaedic Surgeons, in January 1946, differs from the first two volumes in that it is directed toward the problems of

civilian orthopaedic surgery rather than toward those arising from war. Thirteen courses of lectures are included. The regions of the foot and ankle, the hip, and the shoulder are presented, with consideration of their anatomy and of the diagnosis and treatment of associated pathological conditions. Other lectures concern fractures, x-ray interpretation, poliomyelitis, cerebral palsy, physiology, club-foot, and posture.

A distinguished group of surgeons contributed to this work. The volume is well prepared, and the illustrations are lavish in number and of excellent quality. The lectures represent a fundamental approach to the problems of orthopaedic surgery; they are of great value to students, teachers, and practitioners of orthopaedic surgery.

AMERICAN MEDICAL RESEARCH PAST AND PRESENT. Richard H. Shryock, Ph.D. New York, The Commonwealth Fund, 1947. $2.50.

This authoritative and compact summary (325 pages) of a very large and cumbersome subject is sponsored by the Committee on Medicine and the Changing Order, established in 1942 by the New York Academy of Medicine. It is one of a series of monographs "designed to provide the framework for an understanding of the current medical situation and its trends. Contemporary medicine is treated as a product of evolution." Richard H. Shryock is Professor of American History and Lecturer on Medical History at the University of Pennsylvania. He wrote "Development of Modern Medicine" in 1936, and is the author of various articles in the field of medical history.

The book has probably greatest value in its brilliant treatment of the early scientific and cultural influences upon research in America up to the modern age of philanthropic, industrial, and governmental support of research. British, French, and German periods of influence are traced. It is no doubt impossible for anyone to gain a proper perspective of modern trends at this early date after the second World War. Speculations are influenced by unusual modern trends, as illustrated by a statement originating from A. N. Richards: "Actually, a $2,000,000,000 Manhattan Project on cancer—where the basic leads are not yet clear—would probably only waste large sums of money, if it did not do more positive damage." That the issues are even today not yet clear is suggested by the plaintive remark at the end of the book: "The research worker who considers historical perspective a waste of time, who assumes that nothing was done in his field until the last century or even the last decade, and who is indifferent to the larger outcomes, is on much the same level as those laymen who dismiss all research that is not 'practical'."

That the value of basic research is still in doubt, in spite of such notable examples as the great German discoveries of the latter half of the last century, is remarkable. The time lag between basic discovery (original thought) and application in diagnosis or therapy has been enormous; it is not always the result of blindness or lack of potentialities, but may rather be due to lack of knowledge of related fields, necessary to assimilate the implications of the discovery. The author has very properly submerged the contribution of American research, compared to that of other countries, in the description of the whole trend, for medical research transcends international boundaries. In spite of some fundamental American discoveries, one is left with the idea that our contributions have been largely technological. Examples are the development of the use of the sulfonamides, penicillin, and the electron microscope. One hopes that the author some day will develop the theme of what circumstances—historical, environmental, cultural, financial, or legislative—are the most favorable for the development of important discoveries in medical sciences.

The general physician or specialist who has a personal interest in gaining perspective in the growth of medical ideas and introducing himself to current trends will find that this book will give him an excellent introductory course. The references will suggest further reading. For the rest, it will appeal, as John F. Fulton suggests in the Preface, to those actually engaged in medical research, teaching, or medical administration. Those who dispense funds for research should find it of essential importance. It is not easy or popular reading, but it deserves careful, meticulous study.

SPORTS FOR THE HANDICAPPED. Ed. 2. George T. Stafford, Ed.D. New York, Prentice-Hall, Inc., 1947. $5.00.

This concise text of 334 pages by a well-recognized Professor of Physical Education brings to interested readers a mass of material and experience, largely taken from the reconditioning program of the Army hospitals. It emphasizes the importance of physical recreation for those patients convalescing from severe permanent disabilities.

As a ready reference for workers interested in physical medicine, physiotherapy, and occupational therapy, it should serve as a useful manual and guide; and for those physical educators interested in remedial exercises for the physically handicapped, it should fill a place of major importance. For the orthopaedic surgeon and those in allied fields of medicine, the descriptive medical material pertaining to specific disease or injury is not entirely up-to-date.

On the whole, however, from the point of view of the permanently disabled and their later convalescent treatment, this book will provide trained workers in physiotherapy and occupational therapy with a guide, widening the horizon of recreational activities adaptable to the severely handicapped.